OPERATING AND INSTRUCTION MANUAL

MODEL VM-301A
BROADBAND
PHASE ANGLE VOLTMETER
S-1125

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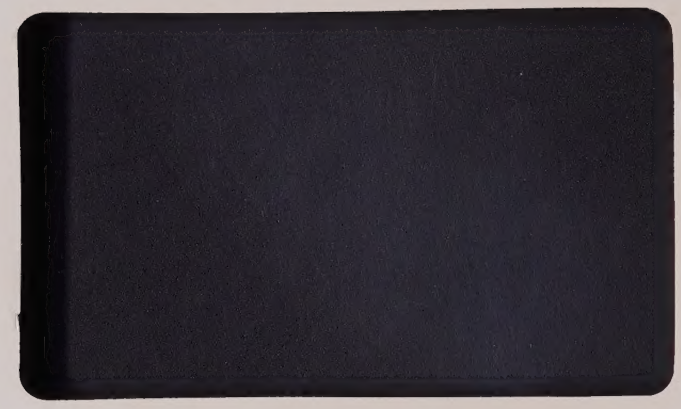

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This equipment is covered by Patents Nos. 3,267,358 and 3,267,359. Other patents are pending.

See Modifications Section for supplements, errata, and instrument revisions.

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Plainview New York

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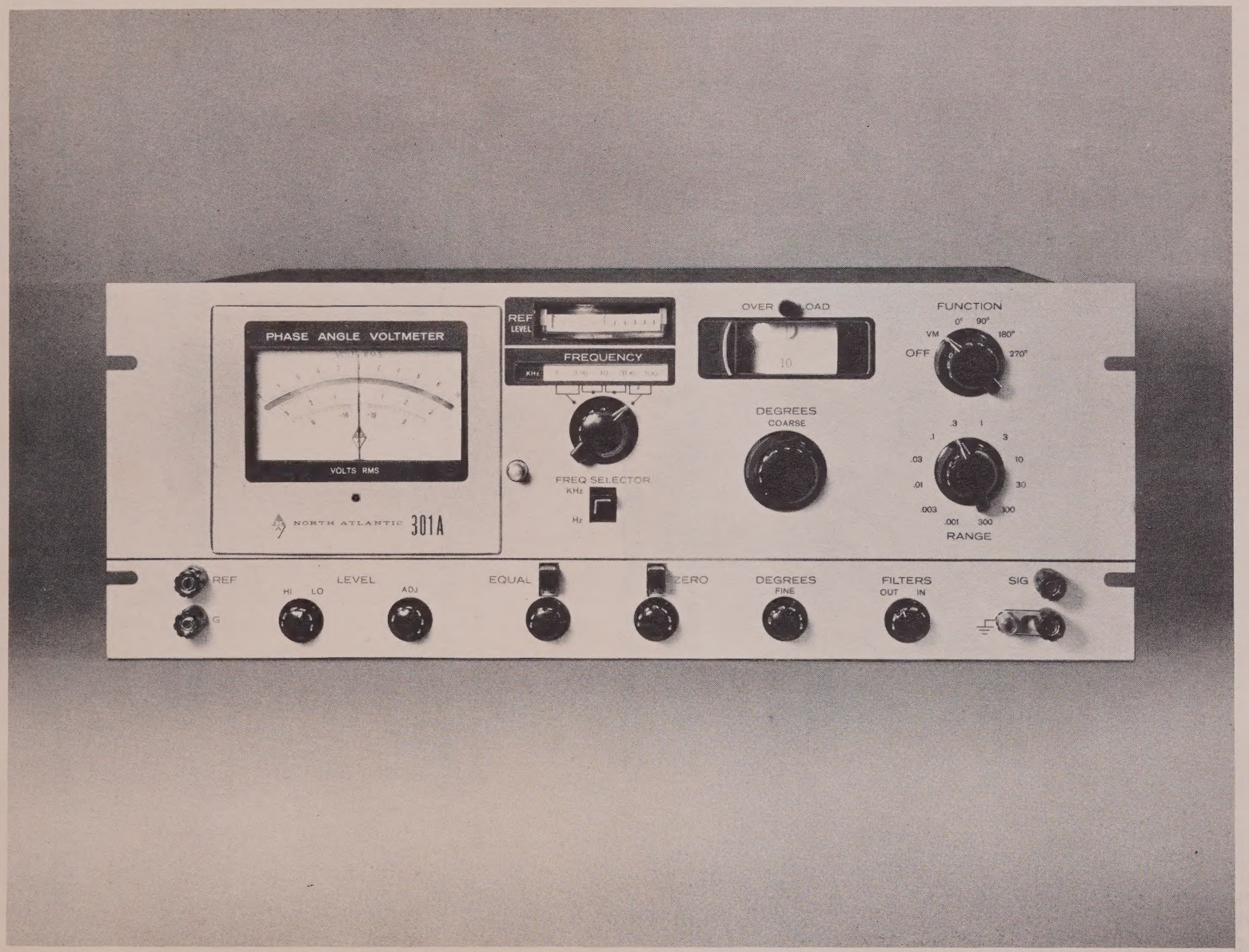
PHASE ANGLE VOLTMETER
VOLTS RMS
NORTH ATLANTIC 301A
REF LEVEL
FREQUENCY
KHz
FREQ SELECTOR
KHz
Hz
OVER LOAD
DEGREES
COARSE
FUNCTION
0° 90°
VM
180°
OFF
270°
.3 1
.1 3
.03 10
.01 30
.003 100
.001 300
RANGE
REF
G
HI LO
LEVEL
ADJ
EQUAL
ZERO
DEGREES
FINE
FILTERS
OUT IN
SIG

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SECTION I

GENERAL DESCRIPTION

INTRODUCTION

The Model VM-301A Broadband Phase Angle Voltmeter, shown in the photograph of Figure 1.1, combines in one instrument the ability to measure both phase angle and magnitude of complex AC signals and their vector components with respect to a reference voltage. Designed to operate over the frequency range from 10Hz to 100KHz, it utilizes passive phase shifter circuits (patents applied for) to assure high accuracy over this spectrum. Because of these broadband characteristics, the Model VM-301A fills a long existing need for a null and phase meter in which the signal frequency may vary. Measurements of AC ratios, phase angles, and related quantities may be made with non-stable frequency sources, or while sweeping frequency to determine phase vs. frequency characteristics.

Front panel controls permit instantaneous selection of range, function and frequency band. As a phase sensitive null meter, the instrument's 2 microvolt sensitivity permits high resolution ratiometric measurements. This requires measurement of low-level voltages of the reference frequency in the presence of noise, hum and other spurious signals. As a phase meter, angles are read on a high resolution, parallax-free scale, calibrated in 0.2^{o} increments. Two simple push and set controls permit trimming to the existing source frequency to achieve best absolute accuracy. Plug-in, interchangeable harmonic filters are available and can be simply installed or removed from the front of the instrument without disassembly.

High input impedance Signal and Reference Channels minimize errors due to loading and common ground signals. Reference levels may be anywhere in the range of 150mv to 150V. Successful measurements can be made with reference levels less than half of the lower value or 75mv.

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APPLICATIONS

A. Phase sensitive null indicator.

B. Measures separately the in-phase and quadrature components of an AC signal.

C. Measures phase shift in any AC system.

D. Sensitive AC vacuum tube voltmeter.

E. Testing of servos, computers, synchros, resolvers, inductosyns.

F. Precise AC ratiometry.

G. Phasing of servo motors, chopper amplifiers, magnetic amplifiers.

H. Measuring both torque and non-torque producing signals in servo amplifiers.

I. Align carrier amplifier and notch networks.

J. Impedance meter.

K. Power factor meter.

L. Measuring response of vibrational system.

Detailed descriptions of these applications are shown in the Application Notes appended hereto.

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ACCESSORIES

Filters

Filters of the low pass plug-in type can be supplied in the range of 28Hz to 28KHz for harmonic rejection in both signal and reference channels. Special band pass filters are available for these and higher frequencies, if necessary. These filters may be plugged into the unit and switched in and our of the circuit from the front with no disassembly.

P-201 Reference Isolation Module

This plug-in module is intended for applications which require that the external reference signal generator be isolated from the Reference and/or Signal Channels of the measuring instrument. It will eliminate errors due to extraneous currents in the signal circuits from common ground connections. The module plugs directly into the banana jacks of the reference input on the North Atlantic Phase Angle Voltmeter.

P-203 Universal Isolation Module

This module is a plug-in transformer module designed for precision bridging and signal or reference isolation application in phase sensitive AC voltage measurements and AC ratiometry. The unique shielding design incorporates special separate shielding of the primary and secondary windings. It can be used as a precision bridging transformer for establishing null voltages in critical AC measurements. Used as a signal isolation transformer, it allows the signal source to be isolated from the measurement instrument and power ground without detriment to the measurement accuracy. This design provides absolute minimum coupling of the primary common mode signal into the secondary winding.

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Other isolation transformers are available for special applications. Information regarding these transformers and their applications may be obtained by contacting North Atlantic Industries, Inc.

NOTE: THE PROPER APPLICATION OF THESE MODULES EXTENDS THE VERSATILITY OF AC PHASE DETECTION AND RATIOMETRIC INSTRUMENTS TO A WIDE RANGE OF MEASUREMENT TASKS IN ACTUAL SYSTEMS WHERE GROUND LOOPS AND EXACT MEASUREMENT CONDITIONS CANNOT BE DEFINED OR PREDICTED IN ADVANCE. THESE PRECISION MODULES ARE DESIGNED TO BE UNIVERSALLY USED WITH ANY AC RATIOMETRIC AND PHASE DETECTION INSTRUMENTS PROVIDED WITH STANDARD 3/4" SPACED BANANA JACKS, SUBJECT TO FREQUENCY RESPONSE.

Front Panel Dress Kit

This kit is available for bench mounting of the instrument. It consists of a front panel trim piece and handles which attach to the ends of the front panel. These handles also contain extendable legs for raising the front of the instrument to improve reading and operating ease.

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GENERAL SPECIFICATION

The following specification applies to all North Atlantic Model VM-301A Phase Angle Voltmeters. Where a special modification or variation is involved, the governing specification will either be a separate specification control document, the buyer's purchase order, or a supplement contained in this manual. Specifications for special instruments are identified by the specification "S" number appearing on the instrument nameplate, e.g., VM-301A-S1234.

Electrical

Voltage Range:	Full scale 1mv to 300V in 12 ranges.
Frequency Range:	Filter Out: VM: 10Hz to 100KHz Phase Sensitive: 10Hz to 100KHz (selected in half-decade steps by front panel control). Filter In: VM and Phase Sensitive: Any frequency within band of 28Hz to 28KHz determined by plug in filters (other frequencies available on special request).
Voltage Accuracy:	Voltage ± 2% full scale over full frequency range.
Calibration:	Meter: Zero center mirror scale, 3-0-3 and 10-0-10 scales. Phase Angle: 0° - 90° calibrated Phase Dial with 0.2° magnified divisions. Dial has 2° overlap into adjacent quadrants selector covers $0\text{-}360^{\circ}$ non-ambiguously.

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Phase Accuracy:	Using Calibrated Phase Dial: 1. ± 0.25° from 31.6Hz to 31.6KHz. 2. ± 31.6KHz to 100KHz: Gradual degradation as frequency is increased to ± 1° @ 100KHz. 3. 10Hz to 31.6KHz: Gradual degradation as frequency is increased to ± 0.6° @ 10Hz.
Sweep Frequency Capability:	(See Text, Section II, "Sweep Frequency Measurement", for discussion). Phase Dial at Cardinal Angles: 2° nominal from 10Hz to 31.6KHz. 7° nominal from 31.6KHz to 100KHz. (Zero and Equal Control set arbitrarily). Phase Dial at 45°, 2.5° nominal. (Equal Control set at approximately 84% or 26% top frequency in half decade.)
Phase Resolution:	0.03° at 10 x overload (1/4 Div.)
Input Impedance:	Signal: 10 megohms, 47uuf, nominal, all ranges. Reference: 10 megohms, 47uuf, nominal. Both high and low ranges.
Reference Level:	Variable from 0.15 to 150V by HI-LO Selector plus Vernier.
Input DC Voltage Level:	DC levels may be applied without affecting performance such that the peak value of the combined AC and DC voltages shall not exceed 600V in the signal input and 1000V in the reference input.

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Overload:	Overload lamp lights at input 11 x full scale setting.
Noise (VTVM):	Less than 10 microvolts in "Filter Out". Less than 20 microvolts in "Filter In".
Nulling Sensitivity (Phase Sensitive):	Less than 2 microvolts in Phase Sensitive Mode.
Harmonic Rejection:	Low pass sharp cut off plug-in filters (28Hz to 28KHz) range rejection of 30DB out side pass band. By proper choice of filter, this may be increased to 50DB for any specific frequency. In addition, detector characteristics reject all even-order harmonics by greater than 55DB as well as odd-order harmonics in inverse proportion to the harmonic order. (-10DB for 3rd harmonic, -14DB for 5th harmonic.)
Non-Coherent Signal Rejection:	For frequencies removed from signal frequency by approximately 5Hz or more (effective pass band of meter movement) response is essentially nil for levels up to 10 times the value of the full scale in use. Appropriate filters can increase the allowable level of the non-coherent signal to 300 times the value of the full scale in use on the most sensitive scales.
Power:	115/125 or 230/250 volts ± 10%, 50Hz to 400Hz, 80 watts. Fused @ 2 amp. for 115/125V operation, 1 amp. for 230/250V operation (3AG Slo-Blo or equal).

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Mechanical

Size:	Panel: 7" x 19" x 1/8" with standard RTMA rack mount slots.
	Depth Behind Panel: 13-1/2"
Weight:	32 lbs. approximate.
Mounting:	Unit can be optionally supplied with front panel decorative bezel and handles with recessible feet, for bench use. These can be removed for rack mounted applications.
Front Panel Paint:	Gray #26440 Fed. Std. 595.
Front Panel Marking:	Black #27038 per Fed. Std. 595.
Power Cord:	6' long minimum.
Front Panel:	Inputs are standard five-way binding posts spaced on 3/4" centers. Ground terminals are colored Black and marked "GND." High side of inputs are Red Terminals. Chrome terminal represents chassis ground.

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SECTION II

OPERATING INSTRUCTIONS

REMOVAL FROM PACKAGE

This instrument has been thoroughly tested, inspected, and evaluated at the factory prior to shipment. Particular care has been taken in the design of the special wrapping and packaging material used in the container to ensure that no damage results from the typical handling encountered during shipment. However, upon removal from package, the instrument should be externally inspected for any obvious damage. Should such be observed, refer to Warranty Policy previously presented.

Prior to making any connection, check meter to see that it reads zero. If it does not, reset the meter to read zero by means of the adjusting screw in the meter door just under the meter face. This adjustment must be done with the power off and with the instrument in a horizontal or near horizontal position.

POWER LINE VOLTAGE AND CABLE

The VM-301A is equipped with a power transformer which has a split primary. All units may be connected to operate from either 115V or 230V. Some instruments contain additional taps which permit operation from higher line voltages (i.e., 125V or 250V, see Power Supply Schematic, Figure 3.9 , for alternate primary configurations).

All standard VM-301A instruments are wired for 115 volts at the factory. The conversion to any of the other configurations may be accomplished in the following manner (see Figure 2.1):

1. Remove jumpers, Pins 4 to 11 and 15 to 16.
2. For 125V, connect Pins 11 to 23, and 18 to 24.
3. For 230V, connect Pins 4 to 16.

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4. For 250V, connect Pin 23 to 24.

All connections between the power input leads and the power transformer primary windings are made to individual terminals on TB4. The above changes and the change of Fuse F1 from 2 amp. to 1 amp. are all that are necessary to make this conversion. TB4 is located below the power transformer on the rear sub-panel.

CAUTION: USE THE PROPER FUSE FOR EACH VOLTAGE.
(3AG, Slow-Blow)

115V/125V Source - 2 Amp Fuse
230V/250V Source - 1 Amp Fuse

All electrical circuit and power grounds are floating with respect to chassis. The instrument is supplied with a three prong power plug, the round pin is wired to the chassis. Common grounding of power, chassis, and circuit ground is accomplished by means of a link on the signal input terminals. The circuit ground must be connected to chassis ground either at the input terminals or remotely. Dependent upon specific applications, it may be more desirable to wire the chassis such that it is not connected directly to house ground.

In those cases, extreme caution must be taken to avoid any personal injuries due to the resultant shock hazard. As a general rule, every effort must be made to ensure that the chassis is wired to a house ground at all times.

CONTROLS, DISPLAYS, INPUTS

Prior to attempting to operate this instrument, it is advisable that the user familiarize himself with every control, display and input connection as described below.

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POWER TRANSFORMER PRIMARY
VARIATIONS - 115V, 125V, 230V, 250V

TOP VIEW

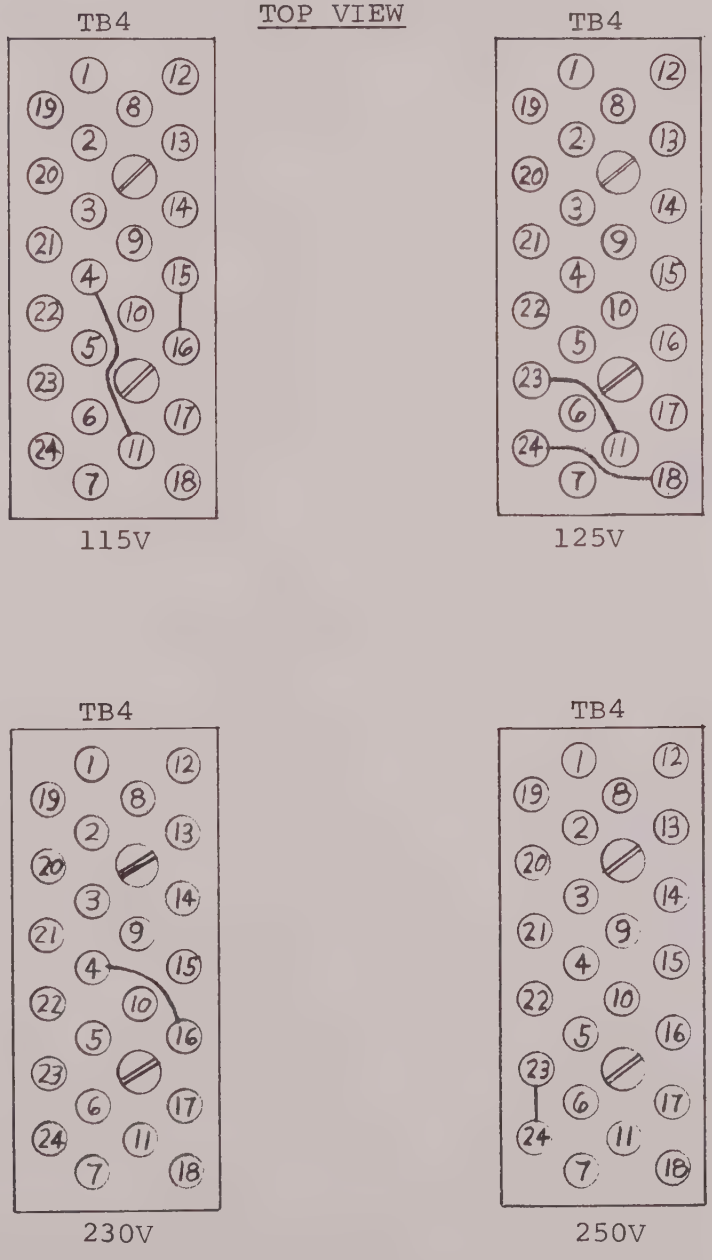

Figure 2.1

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RANGE Switch

A rotary switch which selects the proper multipliers for the desired voltage range. The RANGE Switch indicates the full scale voltage at each position.

FUNCTION Selector

The FUNCTION Selector contains the ON/OFF Switch which turns the instrument on when rotated to any desired mode of operation. In the four Phase Angle Voltmeter positions, the instrument is connected so that it may read a voltage E cos α where α is defined as the angle by which the signal vector leads the reference vector. The FUNCTION Selector selects the quadrant over which the calibrated phase shifter will operate. Thus, the total angle shifted in degrees will be either 0^{o}, 90^{o}, 180^{o}, or 270^{o}, plus the reading of the Phase Dial.

In the VM position, the instrument functions as a standard voltmeter. With the Filter Switch in the "Filter In" position, the instrument will read the total vector voltage of the fundamental signal.

FREQUENCY Selector

This dual switch selects the desired frequency range in half-decade steps. The entire frequency band is divided into two spectrums, 10Hz to 1KHz and from 1KHz to 100KHz. The slide switch selects either the high or low spectrum. The small pointer knob then selects the proper half-decade step within the spectrum. The spectrum and half-decade steps are indicated on the flag which changes position when the Hz/KHz slide is switched.

FILTER Selector

This inserts the harmonic attenuation filters either into or out of the Signal and Reference Channel simultaneously.

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REFERENCE LEVEL Switch and Control

This switch and the associated potentiometer represent the Reference Channel RANGE Selector, allowing the wide range of reference (.15V to 150V) to be used. This is not a calibrated control and for proper adjustment of the Reference HI-LO and Level Control, see the Reference Level Meter description in this section.

NOTE: These controls should be set to maintain an on-scale reading of the Reference Level Meter at all times.

ZERO Switch, EQUAL Switch, and Controls

Combined, these controls perform the necessary trimming of the two Amplifier Channels and Phase Shifter Networks to align the instrument for the most accurate phase measurements at a specific frequency.

Filter Amplitude Adjustment

This control is mounted on the right side of the meter door and is available when the door is open. It is used when changing filters to compensate for the difference in insertion loss associated with the filters. Information regarding its use is presented in the section describing filter operation.

Voltmeter

The meter is a zero center DC milliammeter calibrated to read the RMS value of a sine wave. For "VM" readings, the needle deflects to the right. For "Phase Angle" readings, the meter deflection may be to the left or right. (See Phase Angle Measurement with Calibrated Phase Shifter, this section, for meaning of deflection right or left.) It has calibrated zero center 3-0-3 and 10-0-10 scales.

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CAUTION: BY ITS NATURE, THE INSTRUMENT IS REQUIRED TO HANDLE INPUTS CONSIDERABLY IN EXCESS OF ITS FULL SCALE READING. DAMAGE MAY OCCUR IF THE SIGNALS ARE APPLIED IN A MANNER WHICH WILL DRIVE THE NEEDLE HARD AGAINST THE STOPS. THEREFORE, ALWAYS APPROACH A MEASUREMENT FROM THE LEAST SENSITIVE POSITION AND RETURN TO THIS POSITION BEFORE MAKING CIRCUIT ADJUSTMENTS.

Reference Level Meter

This zero suppressed meter indicates the reference voltage level within the phase shift networks. This is used for phase reference level adjustments and phase network trimming purposes. Its use is described in the section dealing with Reference Level Adjustment. (Note: Set Reference Level Controls to maintain an on-scale reading at all times.)

Phase Dial

A dial which is calibrated to read the degrees of Phase Shift introduced by the calibrated phase shifter network within the particular quadrant selected by the FUNCTION Selector. The dial is calibrated -2^{o} to $+92^{o}$ in 0.2^{o} graduations. Mechanical positioning of the dial on its shaft is critical and for this reason should it be necessary to repair or replace, the procedure under "Phase Dial Alignment" should be followed.

OVERLOAD Indicator

The lamp marked OVERLOAD lights whenever a prescribed signal level is exceeded. As the signal reaches the overload condition, the lamp will blink. A steady glow indicates a large overload condition. This indication warns of impedning amplifier overload and the attendant inaccuracies which will occur when large saturating signals are present. The overload indicator is factory set to blink at eleven (11) times full scale.

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Input Terminals

Five terminals are provided at the front panel for connection to external test circuits. Terminals for both the signal and reference inputs are colored Black for circuit ground and colored Red for the high side of the input. These posts which are on a standard 3/4" spacing will accommodate banana plugs, wire, or alligator clips.

CAUTION: MAXIMUM SIGNAL INPUT MUST NOT EXCEED 600 VOLTS AND MAXIMUM INPUT REFERENCE MUST NOT EXCEED 1000 VOLTS (COMBINED PEAK AC & DC LEVELS). HIGHER VOLTAGES WILL BREAK DOWN THE INPUT CAPACITORS IN THE INSTRUMENT.

A third terminal is provided on the signal input for connecting circuit ground to chassis ground. As the voltmeter circuit grounds are floated above chassis, a link is provided between the metal terminal and the ground (black) terminal of the signal input to allow maximum flexibility of connections. Great care should be given to grounding methods used to avoid ground loops and stray fields. The instrument will not read properly if the input is ungrounded or improperly grounded. The link is provided to permit grounding to a remote point in a measuring set up.

Filters

Harmonic attenuation filters can be supplied in single frequency pairs for a specified band of frequencies in the range from 28Hz to 28KHz. These are plug-in units located behind the meter and accessible by opening the meter door. More information is presented later under "Filter Operation".

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Fuses

The fuseholder mounted on the back of the instrument will accept either a 2 amp Slow-Blow or 1 amp Slow-Blow, 3AG type, depending upon the line voltage as previously described. (See Page 2.2)

OPERATION

Plug the instrument into the proper power source and turn the FUNCTION Selector to any mode. Allow the instrument to warm up about 15 minutes for stable operation. For the most precise phase measurements, additional time should be allowed.

CAUTION: BEFORE MAKING PHASE OR VOLTAGE MEASUREMENTS, REVIEW THE SECTION ON GROUNDING TECHNIQUES IN THE APPLICATION NOTES.

To Measure Voltage

Set the RANGE Switch to the appropriate scale and the FUNCTION Selector to the "VM" position. Connect the voltage to be measured to the signal input terminals. Read the voltage from either the 0-10 volts or 0-3 volts using the proper scale factor as determined by the RANGE Selector position.

With the FUNCTION Selector in the "VM" position and the FILTER Switch in the "OUT" position, the voltmeter operates as a standard AC VTVM. This AC Voltmeter reads the total vector voltage at any frequency including all harmonic effects. With the FILTER Switch in the "IN" position and with the proper filters plugged into the instrument, the voltmeter will read only the fundamental voltage within the range of the filter.

Notice that with no input to the instrument, the meter needle deflects on the low ranges. This condition is normal and represents a true measurement of the stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to effectively zero.

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Switching the instrument into the "VM" position will cause the Reference Level Meter to read off scale to the left. This is normal as the reference is disconnected internally in the "VM" position.

Measurements made on high impedance circuits require that special attention be paid to capacitive as well as inductive pickup. Twisted and/or shielded cable will reduce the effect although the cable capacity could serve to load the source.

Care must also be taken to ensure that error producing ground loops do not exist by virtue of the signal and reference grounds or "low" being connected internally as well as to the instrument case.

Precise Phase Angle Measurements - Preliminary Adjustments

1. Set the FREQUENCY Selector to the proper band for the frequency to be measured.

2. Switch FUNCTION Selector to a phase-sensitive position.

3. Connect the reference voltage to the REF input terminals of the instrument. With the Reference "HI-LO" Switch and REFERENCE LEVEL Control, adjust the reference input to give an on scale reading on the REFERENCE LEVEL Meter. (No particular setting is required, as the instrument will operate over a wide range of reference level. As long as an on scale reading is maintained, the instrument will remain within calibration tolerances.

4. Depress the EQUAL Switch and note if there is any change in REFERENCE LEVEL Meter from that observed in Step 3.

5. With the EQUAL Adjust Knob, readjust the reference meter to original reading. Adjust this control until there is no change in reference level when the EQUAL Switch is depressed or released.

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6. Depress the ZERO Switch and using the ZERO Adjust Knob, adjust the Phase Angle Voltmeter to read exactly zero. Release the ZERO Switch and proceed with the measurements.

NOTE: The above steps have aligned the Phase Angle Voltmeter for accurate measurements at a particular frequency. Maximum accuracy may be had at any frequency in the spectrum of 10Hz to 100KHz by following this procedure. The EQUAL procedure outlined in Steps 4 and 5 need only be done if the Phase Dial is to be used at other than 0^{o} or 90^{o}. (See Theory of Operation).

Phase Angle Measurements - With Calibrated Phase Shifter

1. Adjust the Reference Channel as described in Step 3 above.

2. Set the FUNCTION Selector to "VM" position.

3. Set the RANGE Switch for maximum on-scale reading.

4. Set PHASE Dial to "0 degrees."

5. Set the RANGE Switch down to the next lower position.

6. Turn the Phase Dial for "0" meter reading (null).

NOTE: If "0" reading cannot be obtained in this manner, proceed with Step 7.

7. Switch FUNCTION Selector to "90 degrees" and adjust Phase Dial for "0" meter reading.

8. Switch FUNCTION Selector to the position which results in a positive up-scale reading. This may occur in any of the four Phase Sensitive Function Positions and serves as a means of "Quadrant" Identification.

9. The phase angle is the sum of the FUNCTION Selector setting of Step 8 and the Phase Dial reading.

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Phase Angle Measurements with In-Phase and Quadrature Components

Accurate measurement of phase angle can also be made using the E cos θ or E sin θ characteristics. Voltage measurements are made of the in-phase or quadrature component and of the fundamental signal (VM position with filter in). The quotient will then be the cosine, or sine, or tangent of the unknown phase angle. Trigonometric tables, slide rule, or graphs included in the appended Application Notes are suitable for converting to degrees. The accuracy achievable using this technique depends upon the procedure, and for that reason, it is suggested the Application Notes be reviewed before using this method.

1. With Reference Channel adjusted as described in "Phase Angle Measurements - Preliminary Adjustment", place FUNCTION Selector in 0° position. Set the Phase Dial at 0°.

2. The meter now reads the in-phase component of the signal. This is also E cosine α where α is the angle between the reference and signal.

3. Switch the FUNCTION Selector to 90°. The meter now reads the quadrature component of the signal which is E sine α. In general, one of these components is usually much smaller than the other and for greater accuracy, it is convenient to change the range of the instrument. This can be done until the OVERLOAD lamp lights, thereby warning of an impending overload condition. This light indicates that the total exceeds 11 times the full scale value.

4. Switch the FUNCTION Selector to the VM position. The meter now reads the fundamental component of the signal which is the vectorial combination of the measurements of 2 and 3.

5. Phase Angle can now be determined by using the quotient of any two of the measurements of 2, 3, and 4 and the appropriate trigonometric tables.

$$\alpha = \text{Sin}^{-1} \frac{(E \sin \theta)}{E \text{ Fund}}$$

$$= \text{Cos}^{-1} \frac{(E \cos \theta)}{E \text{ Fund}}$$

$$= \text{Tan}^{-1} \frac{(E \sin \theta)}{E \cos \theta}$$

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Sweep Frequency Measurements

If it is desired to make less accurate phase measurements while sweeping frequencies, it is possible to accomplish this without adjustment of the EQUAL or ZERO controls. To do this, it is necessary to understand the two sources of error inherent in this procedure.

The first is the phase misalignment between the Reference and Signal Channels that occurs as the frequency is varied. This is generally small within each half decade but can increase to a few degrees as the frequency is varied from decade to decade. This error will affect accuracy at all angles of the Phase Dial. If it is desired to minimize this error, an adjustment of the ZERO control in the middle of each half decade band can be made.

The second source of error is due to the difference in the amplitude gradients of the internally generated 90^{o} and 0^{o} signals applied to the phase bridge. (See Theory of Operation.) The 0^{o} signal is relatively constant with frequency, but the 90^{o} signal varies in an identical parabolic manner from half decade to half decade. This voltage is a maximum at the two extremes of the half decade, dipping in the middle of the band to a value 18% below the value at the extremes. This pattern is repeated in every half decade. This parabolic curve is shown in Figure 2.2 for the 1KHz - 3.16KHz band. The function of the EQUAL control is to adjust the 0^{o} and 90^{o} voltage to equal amplitude. The error due to these two voltages not being equal is maximum at 45^{o} of the Phase Dial (0.28^{o}/% of difference in amplitude) and has no effect at the 0^{o} or 90^{o} position of the Phase Dial. Since this pattern is repeated from half decade to half decade, it is possible to adjust the EQUAL Control at one point in a half decade in such a way that the variation of the 90^{o} signal amplitude is ± 9% (see Figure 2.2) from this value and this pattern will be repeated in every other half decade. The frequency to make this adjustment is approximately .84 or .36 of the maximum frequency of the half decade. This will limit the maximum error to ± 2.5^{o} at the 45^{o} position of the Phase Dial. The error will be less at other positions of the Phase Dial.

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90° Signal Amplitude Characteristics

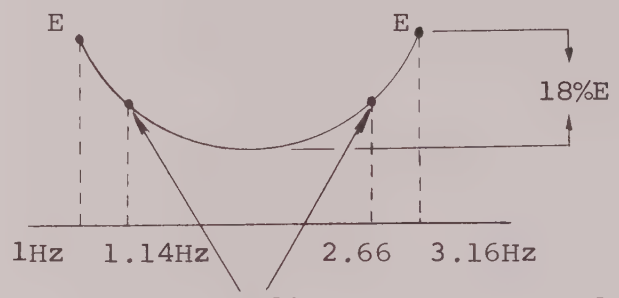

Figure 2.2

FILTER OPERATION

General

Due to the potential errors in making phase measurements on signals containing significant harmonics, it is usually necessary to use harmonic filters to achieve the ultimate accuracy of this measurement. It is also sometimes desirable to make non-phase sensitive measurements on input signals after removing noise and harmonic components. Therefore, provision is made for switching filters into both channels using the Filter "In-Out" Switch while making both phase sensitive and non-phase sensitive measurements.

The filters used are plug-in, low pass types. The filters are operated in a restricted portion of the pass band in order to maintain, over this band, the amplitude gradient within the instrument specification and to restrict the phase variation. It will then be possible at any frequency within the band (see below) to make adjustments in the in the Filter "Out" position and switch to the Filter "In" position without having to make any further adjustment.

Two types of filters have been available for both the VM-301 and the VM-301A. Their identification and salient features are shown in Table 2.1. The newer filter, designated as the 782234 series, is an improved version, which supercedes the

older 782281 type. Their use results in: greater bandwidth, higher harmonic rejection, and a few number of filters to cover the frequency spectrum (see Tables 2.2 and 2.3):

TABLE 2.1

Type	fa Band		fp Band	
	Bandwidth for 1% Amp. Grad.	3rd Harmonic Rev. at Lowest Frequency	Bandwidth for 2% Amp. Grad.	3rd Harmonic Rev. at Lowest Frequency.
782281 (Old type)	.87fm to 1.15fm BW=fm±15%	30db	.78fm to 1.25fm BW=fm±25%	20db
782234	.71fm to 1.41fm BW=fm±41%	30db	Not Rated	

Usable bandwidth limits are determined as follows:

f_m designates the geometric mean frequency of the usable band.

Upper frequency limit is determine by the amplitude vs. frequency characteristic. Lower frequency limit is determined by the amount of rejection of the third harmonic of this frequency.

Bands designated f_a ($.87f_m$ - $1.15f_m$) will have a maximum amplitude variation of 1% over the frequency band and 30DB* rejection of the third harmonic of $.45f_o$. (f_o is the frequency where the amplitude is down 6DB* from the low frequency amplitude.

*NOTE: When making phase sensitive measurements, the detector circuit inherently has a high second harmonic rejection (approximately 55DB) and 10DB additional rejection of the third harmonic.

This additional harmonic rejection is, therefore, added to the filter rejection when operating in any phase sensitive mode.

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Table 2.2 is a complete listing of the 782081 series with Figure 2.3 showing a typical characteristic curve for these filters. Table 2.3 is a complete listing of the 782234 series with Figure 2.4 showing a typical characteristic curve for these filters.

Usable band limits were determined by the same criteria as the 782081 series. f_m designates the geometric mean frequency of the usable band. The usable band in this case, however, is not designed in the same manner. The upper limit is designated and is determined by $1.41f_m$ with a maximum amplitude variation of 1% over the frequency band. The lower limit is designated and determined by $.71f_m$ with a minimum rejection of 30DB of any frequency in the band.

It is possible to extend the range of any filter if additional attenuation is desired. If this is done, the filter adjustments described on the following page must be made at each frequency used, and the usable bandwidth around this frequency is severely limited. It is not recommended that a frequency of $1.62f_m$ be exceeded.

NOTE: In general the instrument without filters has inherent harmonic rejection (see Pages 3.14 through 3.19). Therefore, the harmonic rejection with filters is the sum of the filter rejection described above and and the instrument rejection described on Pages 3.14 through 3.19.

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Filter Adjustment

Pull out meter drawer and insert desired filters into octal sockets.

Amplitude Adjustment:

a. Put in any convenient level of input signal at the f_m frequency of the filter.

b. Place FUNCTION Switch in the "VM" position.

c. Turn Filter In-Out Switch to "OUT" position.

d. Turn RANGE Switch to range corresponding to on scale reading with signal input available.

e. Observe reading on meter. This should be as close to full scale as possible.

f. Switch to Filter In position and adjust R105 Filter Level Adjustment for the identical reading observed in Step "d". This control is mounted on the right side of the meter door behind the voltmeter.

g. No further adjustment need be made in R105.

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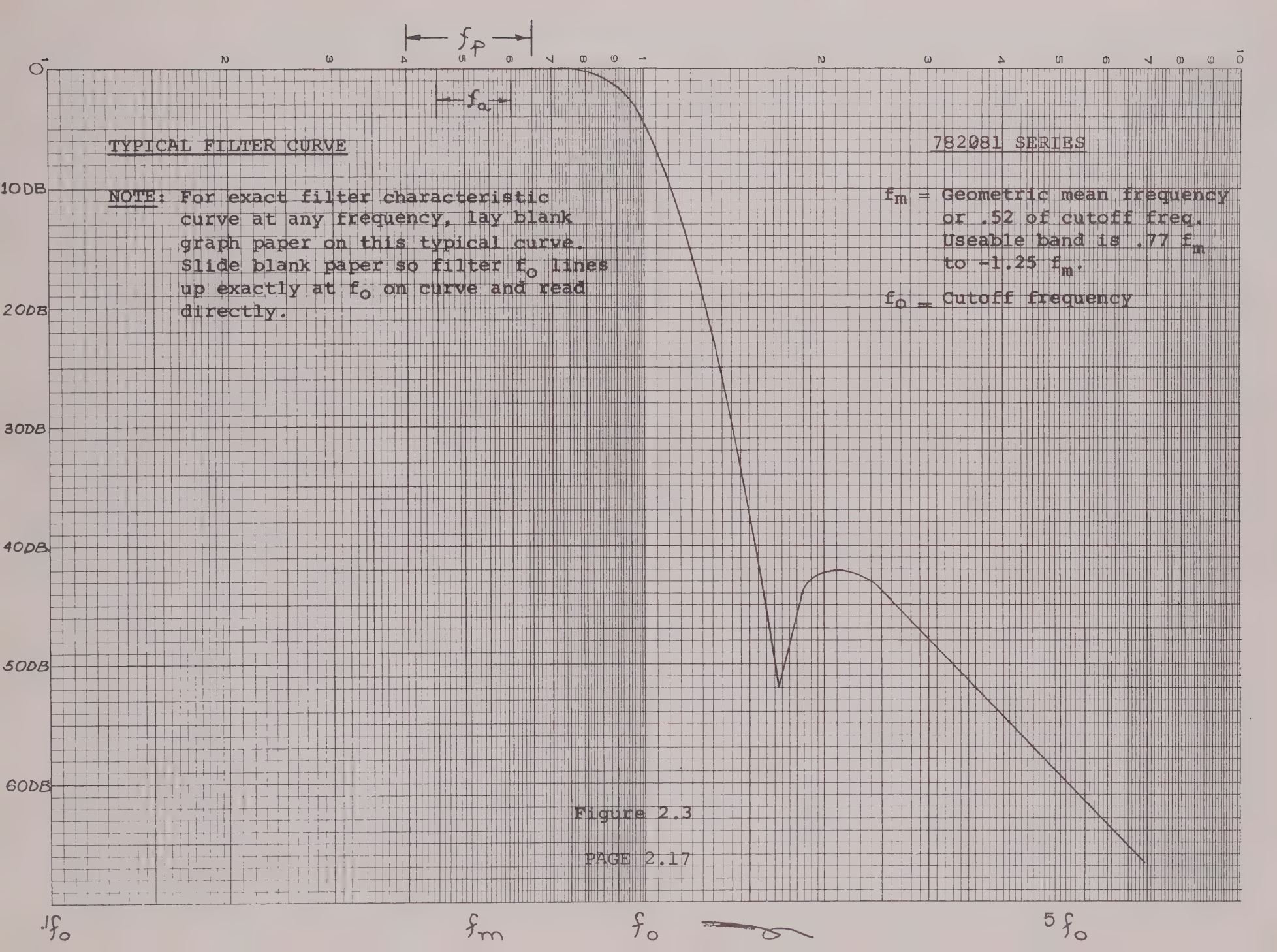
f_p
f_a
TYPICAL FILTER CURVE
NOTE: For exact filter characteristic curve at any frequency, lay blank graph paper on this typical curve. Slide blank paper so filter f_o lines up exactly at f_o on curve and read directly.
782081 SERIES
f_m = Geometric mean frequency or .52 of cutoff freq. Useable band is .77 f_m to -1.25 f_m.
f_o = Cutoff frequency
0
10DB
20DB
30DB
40DB
50DB
60DB
.1f_o
f_m
f_o
5f_o

Figure 2.3

TABLE 2.2

PART NO.	fm	f_a (.87f_m-1.15f_m)			f_p (.78f_m-1.25f_m)		
782081-2	52.0	45	to	60	40	to	65
782081-3	62.5	54	to	72	48	to	78*
782081-4	83	72	to	96	64	to	104
782081-5	104	90	to	120	82	to	130*
782081-6	130	113	to	150	101	to	162
782081-7	156	136	to	180	122	to	195*
782081-8	260	225	to	300	200	to	325
782081-9	208	180	to	240	162	to	260
782081-10	416	360	to	480	325	to	520
782081-11	520	450	to	600	400	to	650*
782081-12	346	300	to	399	270	to	432*
782081-13	780	680	to	900	620	to	975*
782081-14	675	585	to	780	520	to	845
782081-15	1.04KC	900	to	1200	820	to	1300
782081-16	1.56KC	1360	to	1800	1220	to	1950
782081-17	2.08KC	1800	to	2400	1620	to	2600
782081-18	2.6KC	2260	to	3000	2050	to	3250
782081-19	1.3KC	1125	to	1500	1015	to	1620*
782081-20	3.12KC	2725	to	3575	2430	to	3900*
782081-21	5.2KC	4500	to	6000	4000	to	6500*
782081-22	4.15KC	3600	to	4750	3240	to	5200
782081-23	6.11KC	5300	to	7000	4750	to	7600
782081-25	7.8KC	6800	to	9000	6200	to	9750*
782081-26	9.53KC	8250	to	11000	7400	to	11915

* This indicates filters which may be omitted when using f_p accuracy and still have complete frequency coverage.

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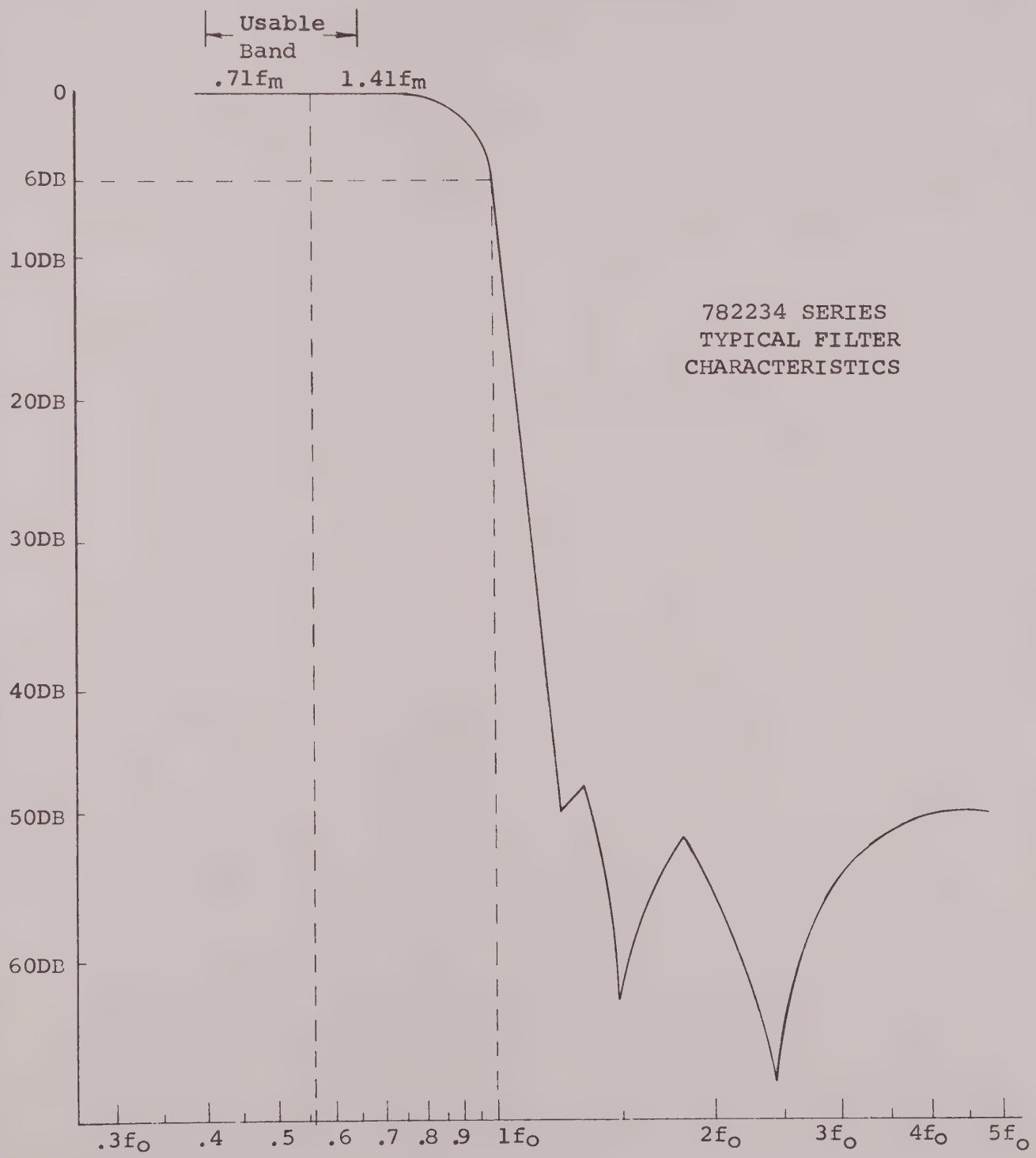

Figure 2.4

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TABLE 2.3

Model No.	Part No.	Usable Band	Remarks
FM-21-*	782334-11	27.5Hz to 55Hz	
FM-21-*	782334-1	55Hz to 110Hz	
FM-21-*	782334-2	110Hz to 220Hz	
FM-21-*	782334-3**	220Hz to 440Hz	
FM-21-*	782334-10	265Hz to 530Hz	
FM-21-*	782334-4**	525Hz to 1050Hz	
FM-21-*	782334-5	800Hz to 1760Hz	
FM-21-*	782334-6	1760Hz to 3520Hz	
FM-21-*	782334-7	3520Hz to 7040Hz	
FM-21-*	782334-8	7040Hz to 14.1KHz	
FM-21-*	782334-12	14.2KHz to 28.2KHz	

Filters may be specified either by NAI Part Nos.

or by Model Nos followed by the *Operating Frequency.

**NOTE: -3 Not recommended for 400Hz. Use -10
-4 Preferred for 1KHz.

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SECTION III

THEORY OF OPERATION

The functional schematic of Figure 3.1 will serve to illustrate the principle of operation of the Phase Angle Voltmeter in its entirety. Note that detailed schematics showing all components are also included in Figures 3.2 through 3.11.

SIGNAL CHANNEL

Input Attenuator and Preamplifier (Figure 3.2)

The 1000:1 resistive divider feeds into the grid of cathode follower (V101). A six step voltage divider forms the cathode resistor for this tube. Connection for both of these attenuators is accomplished by the RANGE Switch (S1). For inputs from .001 to .3 volts, the signal is applied directly to the grid of V101. For inputs of 1 to 300V, the signal is attenuated by 1000:1. The six step divider switch section is arranged so that its rotor has two moving arms located 180^{o} apart. As the RANGE Switch is rotated through its full range of rotary travel, contact is made twice with each of the six taps; once for the six low ranges; once for the six high ranges. On the six high ranges, the input signal is divided down before it is applied to the six step divider, each tap on the divider serves two ranges, giving a total of twelve ranges. Connections on both attenuators are arranged so that the output of the six step divider is maintained at approximately .001 volts which corresponds to full scale voltage for each range.

The RC Networks on the six step divider serve to reduce switching transients and maintain proper ratios at all frequencies. The 1000:1 attenuator is a broadbanded attenuator maintaining its ratio and zero phase over the

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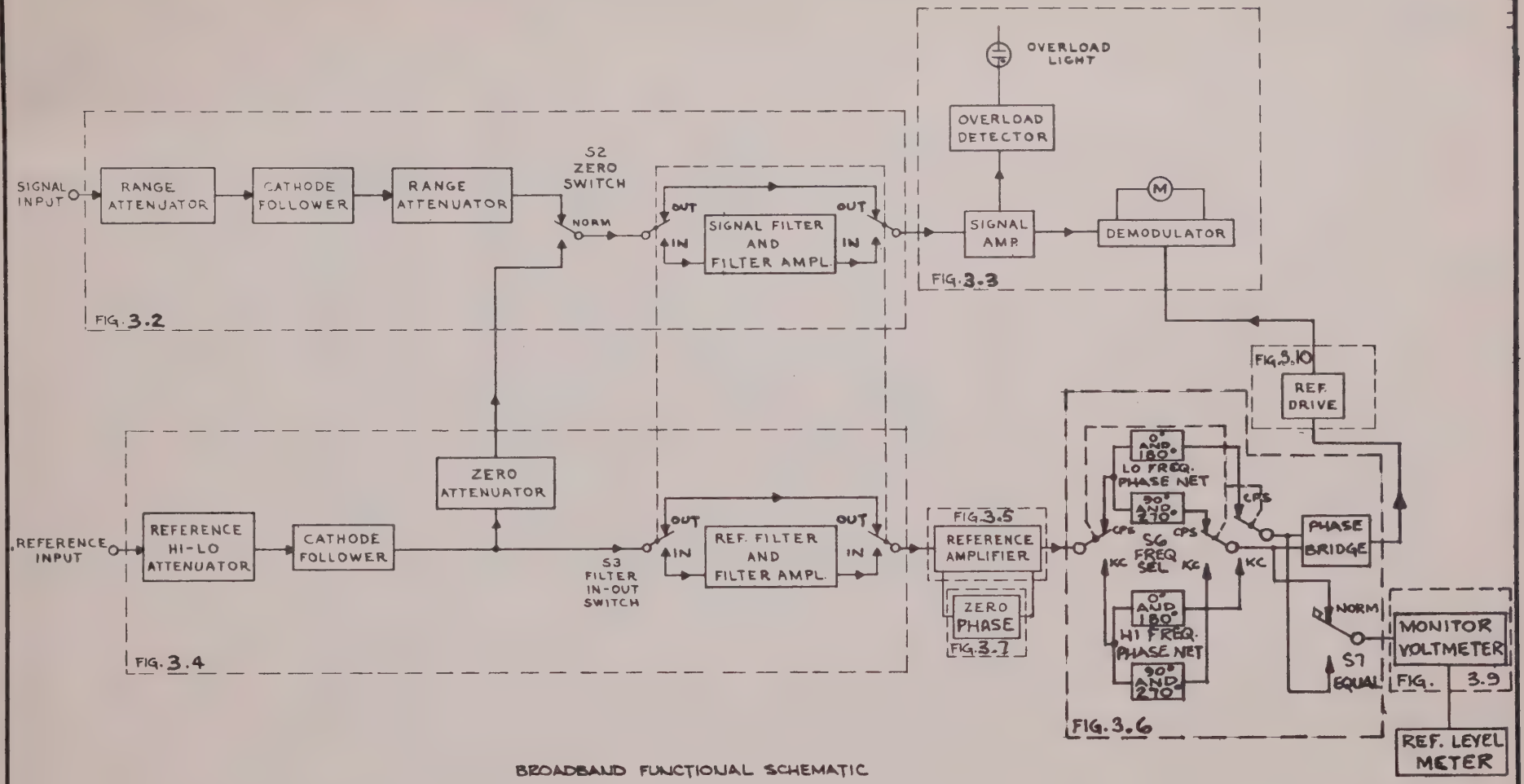

BROADBAND FUNCTIONAL SCHEMATIC

FIGURE 3.1

entire band of frequencies.

When no filters are employed, the cathode follower (V101) output is applied directly to the input of the main signal amplifier. When filters are used, the output of the cathode follower is applied by means of the Filter Switch to the second 6AB4 (V102). This stage operates as a low gain amplifier to supply the proper driving impedance for the filter, and to compensate for filter insertion loss. Amplitude recalibration of the voltmeter when changing filters is accomplished by potentiometer, R105. The adjustment is located on the meter door. The proper adjustment procedure for this calibration is described under "Filters."

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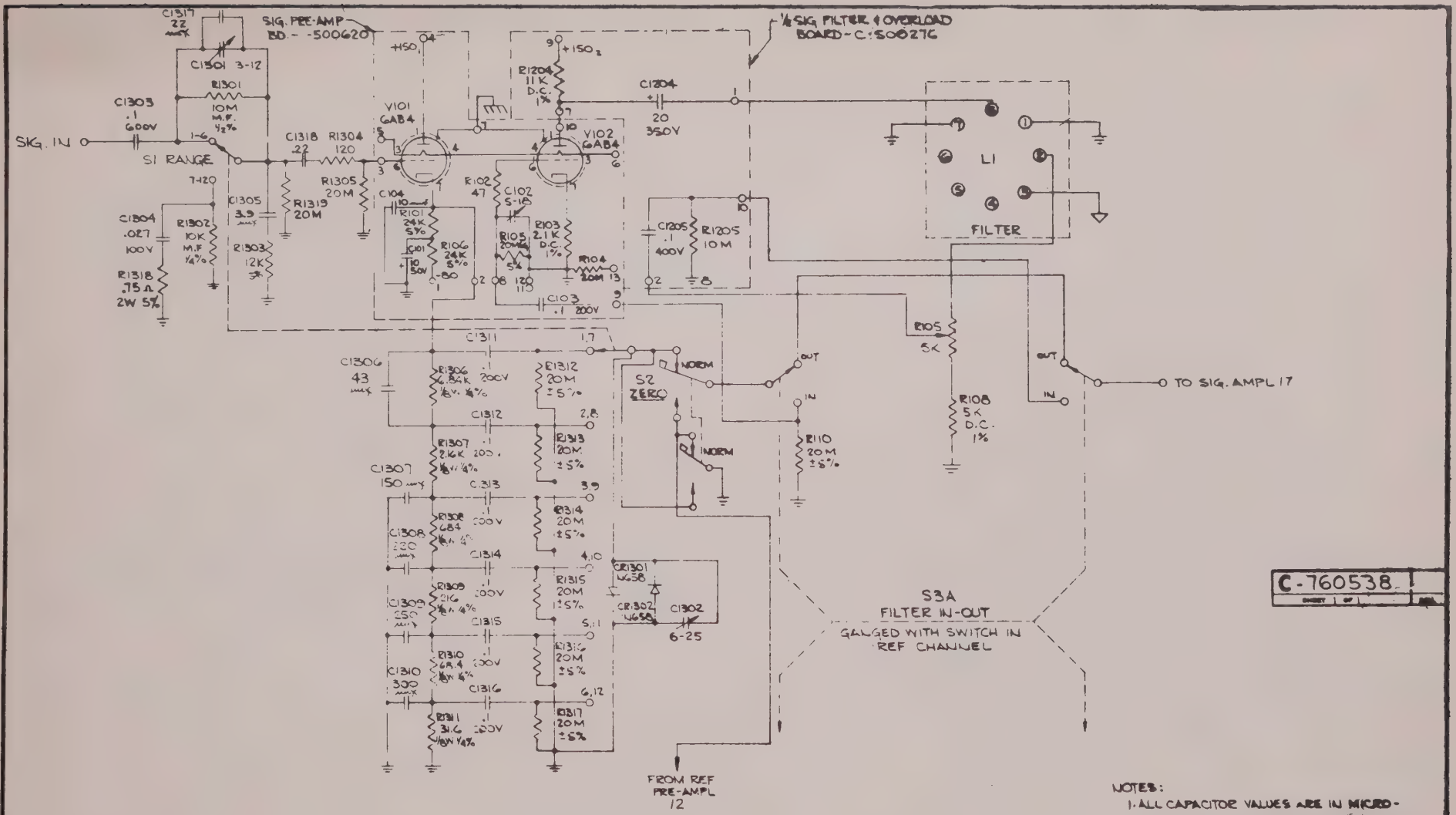

SIGNAL PREAMPLIFIER
Figure 3.2
Page 3.4

Signal Amplifier (Figure 3.3)

This four-tube amplifier provides high gain over a wide frequency range. The output of the amplifier drives the phase-sensitive detector and an indicator circuit which is biased by means of R1202 or in order to indicate overload conditions. A high degree of stability is obtained by the use of negative feedback. The pentode section of the dual tube (V204) drives the detector and meter circuit. The amplifier feedback is returned from the plate of this tube through the meter rectified circuit to the cathode of the first amplifier tube (V201). The overall gain of the amplifier is adjusted by means of the calibration potentiometer (R242) located on the back panel of the voltmeter.

The second half of V204 is used to operate the overload circuit. The point at which the light illuminates is adjusted by means of potentiometer R1003 mounted on the chassis to the rear of the phase pot housing.

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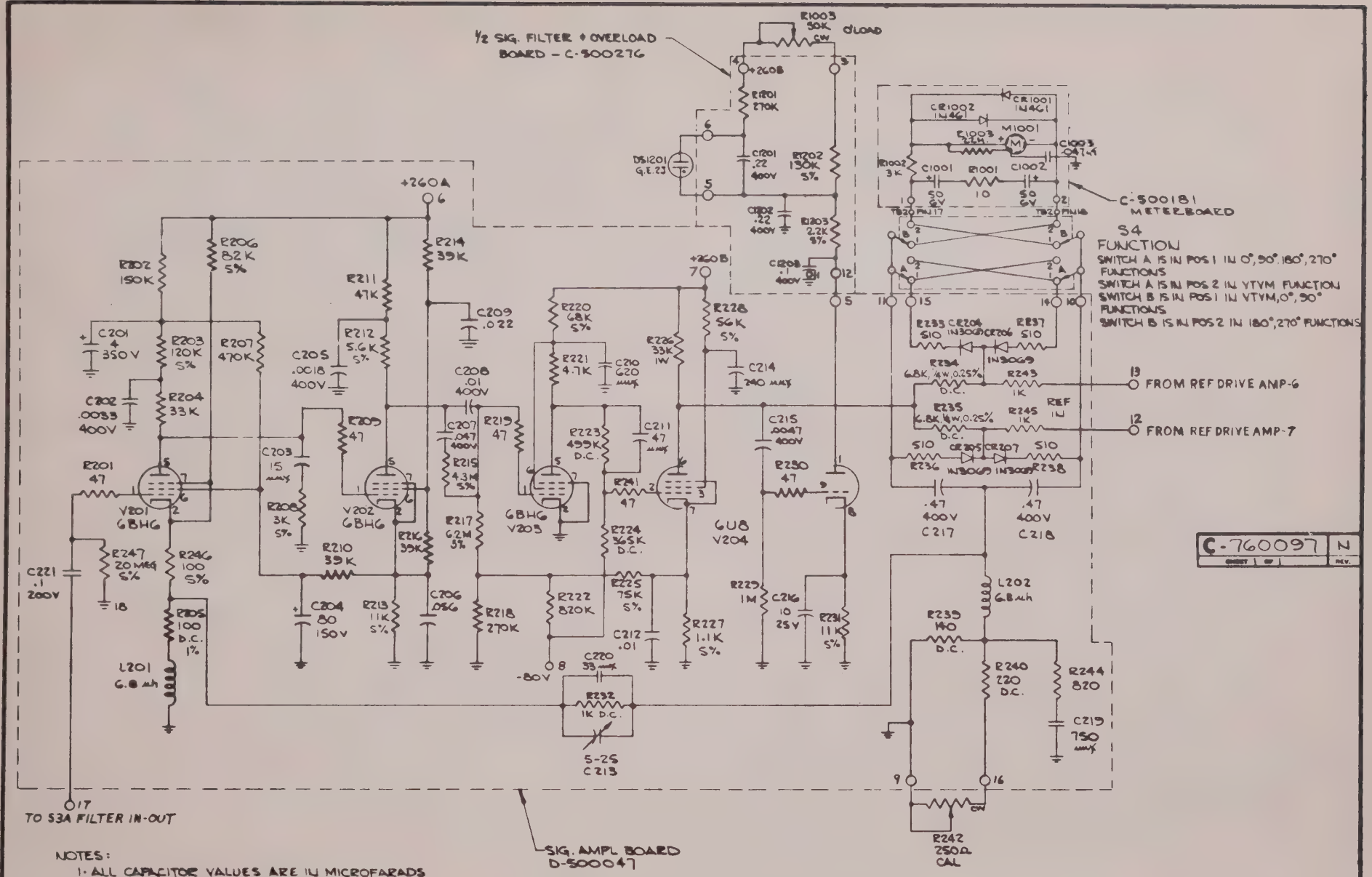

NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½ W, ±10% UNLESS OTHERWISE SPECIFIED

SIGNAL AMPLIFIER
FIGURE 3.3
Page 3.6

REFERENCE CHANNEL

Input Attenuator and Preamplifier (Figure 3.4)

A 30:1 resistive broadband divider feeds the grid of cathode follower (1/2 of V301). Afrequency compensated potentiometer forms the cathode resistor for the tube. The combination of these two attenuators allows the Reference Channel to be adjusted over the range of .15 to 150V input.

When no filters are employed, the signal is applied directly to the grid of the first reference amplifier tube.

When a reference filter is used, the output of the cathode follower is applied, by means of the Filter In-Out Switch, to the second half of V301. This stage operates as a low gain amplifier to supply the proper driving impedance for the filter and compensates for the insertion loss in the filters.

Reference Amplifier (Figure 3.5)

This three tube amplifier supplies the necessary gain and low impedance output required for driving the phase shifting networks. Frequency response and phase shift characteristics are carefully controlled by compensating networks in the plate and cathode circuits. Negative feedback in the cathode of the input tube is passed through networks selected by the FREQUENCY Switch for proper frequency shaping. The second half of the input tube, operating as a phase shifter, feeds two cascaded push-pull stages.

The output stage, consisting of the two triodes, operates similar to a cathode follower with transformer coupled output. In order to cover the complete frequency band, one transformer is used for the low band and a different transformer is used for the high band. The proper unit is selected by the FREQUENCY Switch. The feedback network of this amplifier

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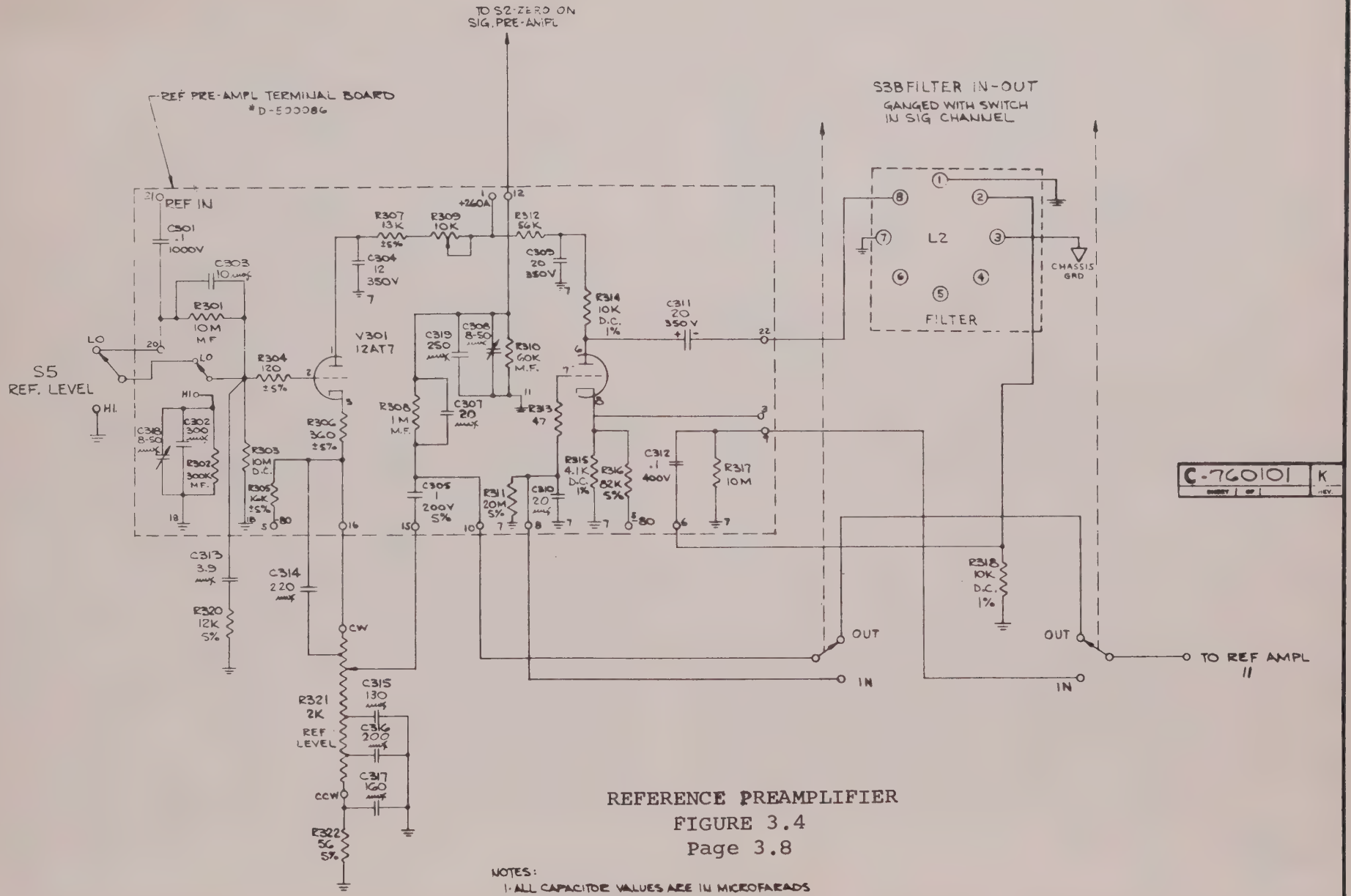
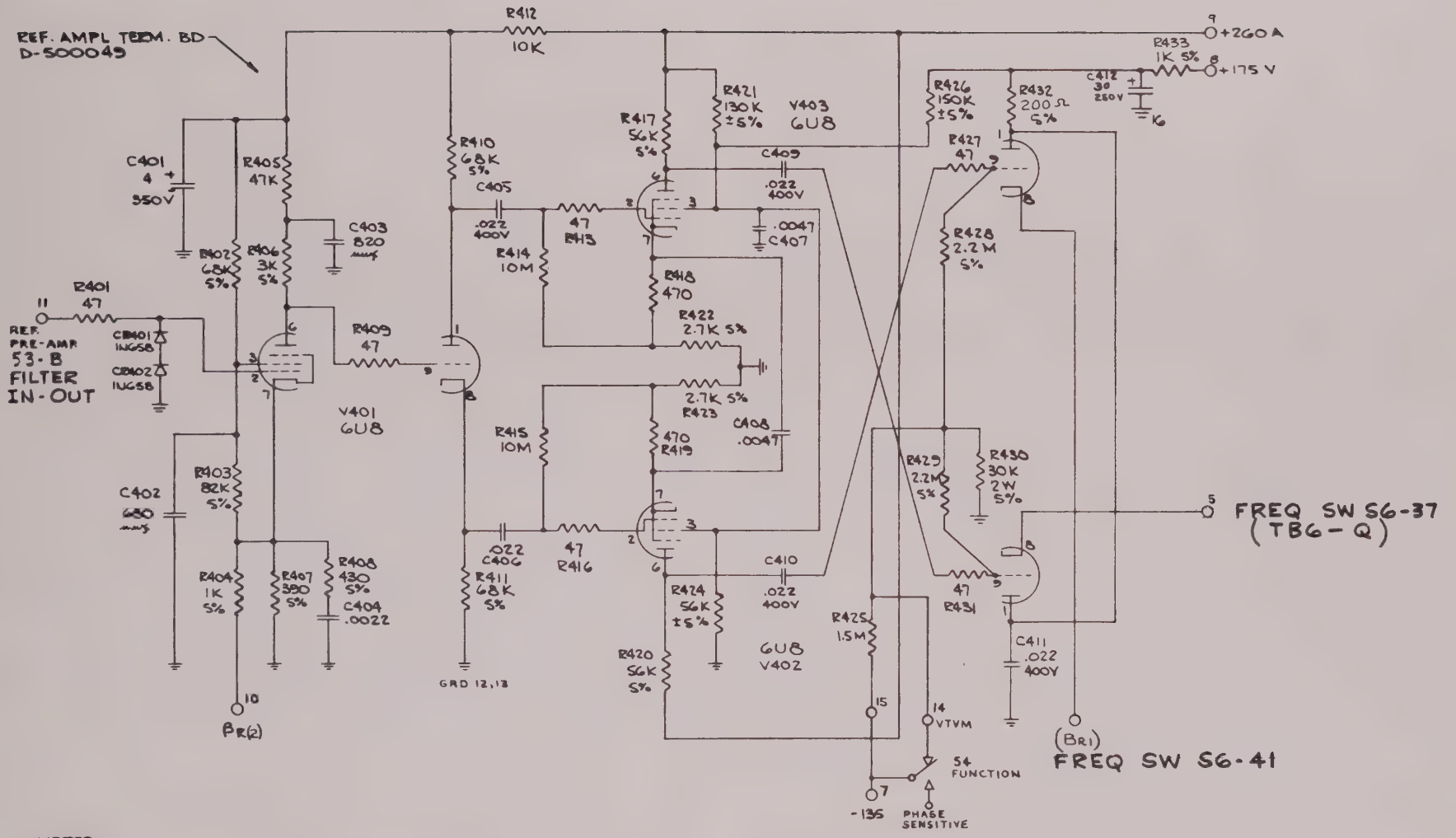


REFERENCE PREAMPLIFIER
FIGURE 3.4
Page 3.8

NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE 1/2W ±10% UNLESS OTHERWISE SPECIFIED



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE 1/2W, ±10% UNLESS OTHERWISE SPECIFIED
3. SEE PAGE 5.2 FOR D.C. VOLTAGES

REFERENCE AMPLIFIER

FIGURE 3.5

is used to phase shift the entire Reference Channel when operating the ZERO Control. Proper condensers are switched into this network as the FREQUENCY Selector is rotated allowing plus and minus phase adjustments.

Phase Networks

A unique, patented, passive phase network design is used to establish $+90^{o}$ and -90^{o} voltages. The 0^{o} and 180^{o} voltages which are derived from the center tapped secondary of the reference output transformer also represent the source for the phase networks. The four outputs resulting from this circuit configuration (0^{o}, $+90^{o}$, -90^{o}, and 180^{o}) are applied to a resistive bridge, one leg of which is the calibrated variable phase potentiometer. By switching the potentiometer with the FUNCTION Selector, between the 0^{o} and 90^{o} voltages and then between the $+90^{o}$ and 180^{o} voltages, the instrument can be switched into the 0^{o} and 90^{o} quadrants. By repeating the above procedure and reversing the meter, the instrument is then switched into the 180^{o} and 270^{o} quadrants.

ZERO and EQUAL Control

These controls, which are an integral part of the phase networks, perform trimming adjustment to compensate for the frequency and amplitude characteristic of the phase network filters. Over such a large frequency range, it is inevitable that small differences in phase between the Signal and Reference Channel occur. On conventional phase angle measuring instruments, this difference is measured by connecting the reference signal into the Signal Channel. If this is to be done during a measurement, then it is usually necessary to readjust the RANGE Switch, FUNCTION Selector, and Phase Dial to positions different from that used during the measurement. The ZERO control on the VM-301A will automatically switch a portion of the reference through a broadband attenuator into the Signal Channel, at a level equivalent to a 6 x overload,

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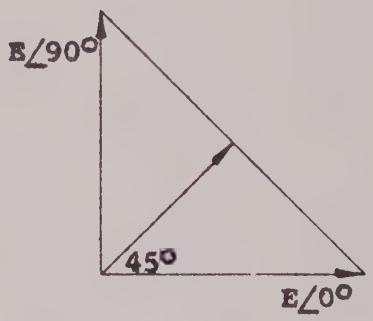

Figure 3.6a

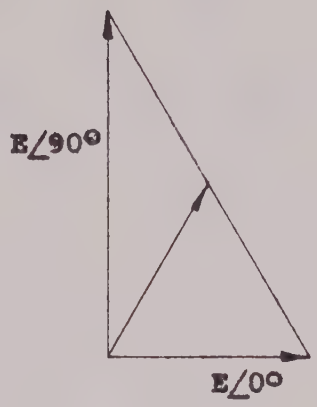

Figure 3.6b

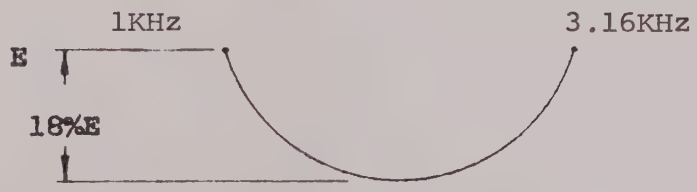

Figure 3.6c

90° Signal Amplitude Characteristics

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independent of the position of the RANGE Switch. This switch will also switch the instrument into the 90° position indepedent of the position of the FUNCTION Selector or the Phase Dial. Thus, one can make this adjustment, while making a measurement, without disturbing the instrument. The ZERO Control is a phase shifter in the Reference Channel, which is used to reduce the phase difference between the Signal and Reference Channels to zero. It is noted that the input sections of both Signal and Reference Channels contribute no phase error as a result of their careful circuit design.

The need for the EQUAL Control can be best illustrated by the vector diagrams shown in Figure 3.6. Figure 3.6a shows the vector voltage E that appears at the center of the phase pot when the 0° voltage is equal to the 90° voltage. It is apparent that the phase of this voltage is 45°. Figure 3.6b shows this same voltage at the center of the phase pot when the 90° voltage is much larger than the 0° voltage. It is evident that the phase of this voltage is no longer 45°. The error that exists at 45° (point of maximum error) is 0.28°/% difference of the two magnitudes. There is no error due to this effect at 0° or 90° on the Phase Dial.

The 90° signal amplitude characteristic in each half decade of frequency follows the characteristic curve shown in Figure 3.6c for the 1KHz - 31.6KHz band. Thus, to ensure Phase Dial accuracy at angles other than 0° and 90°, the in-phase network amplitude must be adjusted so that it is equal to the 90° network amplitude. This is performed by measuring the 90° network amplitude on the monitor meter (Figure 3.7) while the EQUAL Switch is in its normal position. By depressing the EQUAL Switch, the in-phase amplitude is measured through the same monitor amplifier and meter and adjusted equal to the 90° amplitude.

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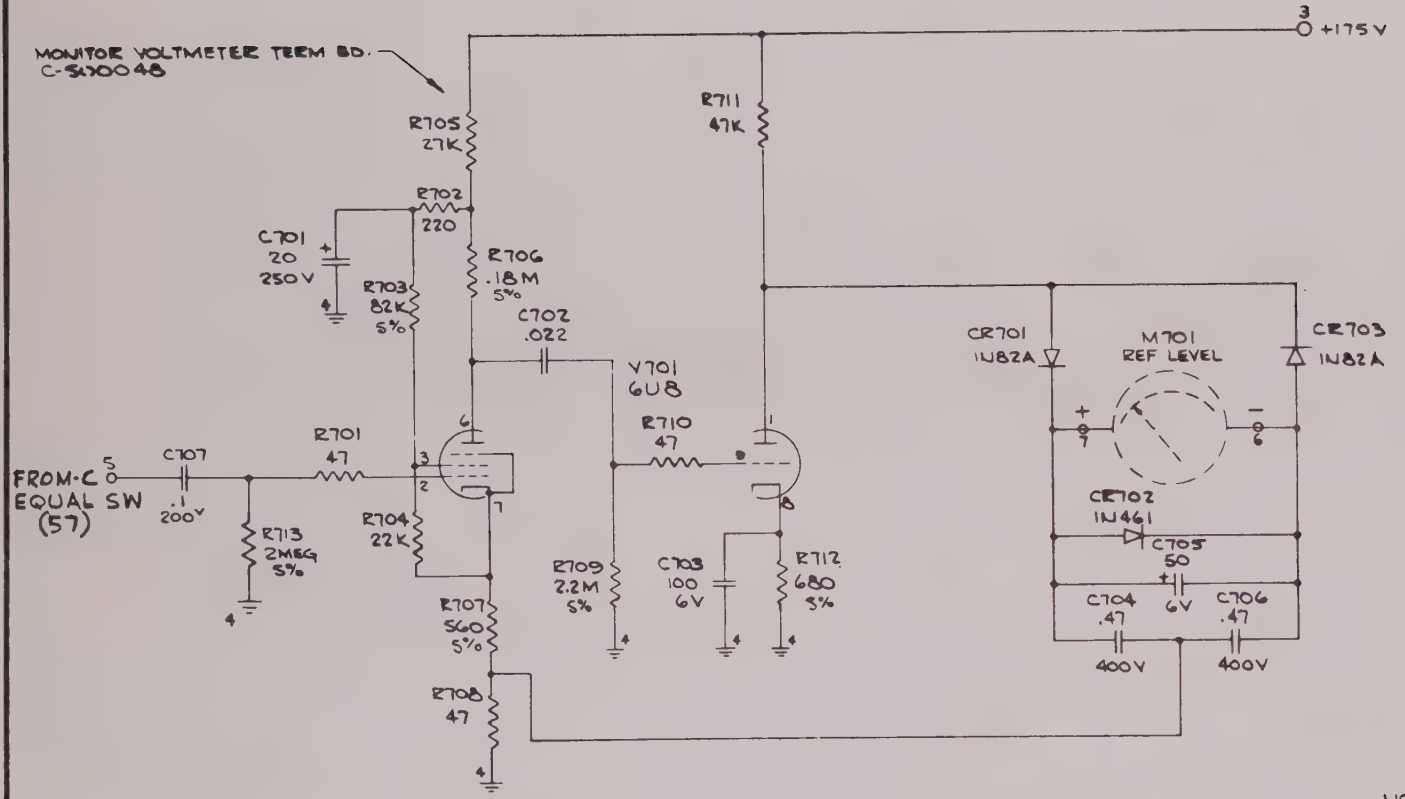

MONITOR VOLTMETER
FIGURE 3.7
Page 3.13

NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE 1/2W, ±10% UNLESS OTHERWISE SPECIFIED
3. SEE PAGE 5.2 FOR D.C. VOLTAGES

Reference Drive Amplifier (Figure 3.8)

This amplifier receives the signal from the calibrated phase potentiometer and drives the reference side of the phase sensitive detector when the FUNCTION Switch is in any of the phase-sensitive positions. This amplifier is a wide band, highly stabilized, phase corrected amplifier. Its purpose is to drive the phase sensitive demodulator without using a transformer as this would severely limit the frequency capability. The input signal is also inverted twice through V801 and V802 and fed back to the phase pot arm through C645 to unload the capacity to ground on the arm of the pot.

Phase Sensitive Rectifier

The Demodulator's phase-sensitive operation (see Figure can be likened to that of a set of commutating switches. The reference signal alternately connects one side of the meter to ground through resistors R240 and R242, then the other end on the revese cycle of the reference. The signal is, therefore, synchronously rectified through the meter movement. When the reference and signal are in-phase (Figure 3.9A) the average value will be a maximum and the meter will read a maximum. When the signals are 90^{o} apart, (Figure 3.9B) the average will be a zero and no reading will result. The equation governing this is:

$$I_{Meter\ (avg)} = K E \cos \theta$$

Where K = proportionality constant
E = RMS of signal
θ = angle between signal and reference.

Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. For improved accuracy under special conditions, the reference level may always be raised to maximum reading on reference level meter for high signal levels. Measurements at the quadrature null point ($\alpha = 90^{o}$) are unaffected by saturation.

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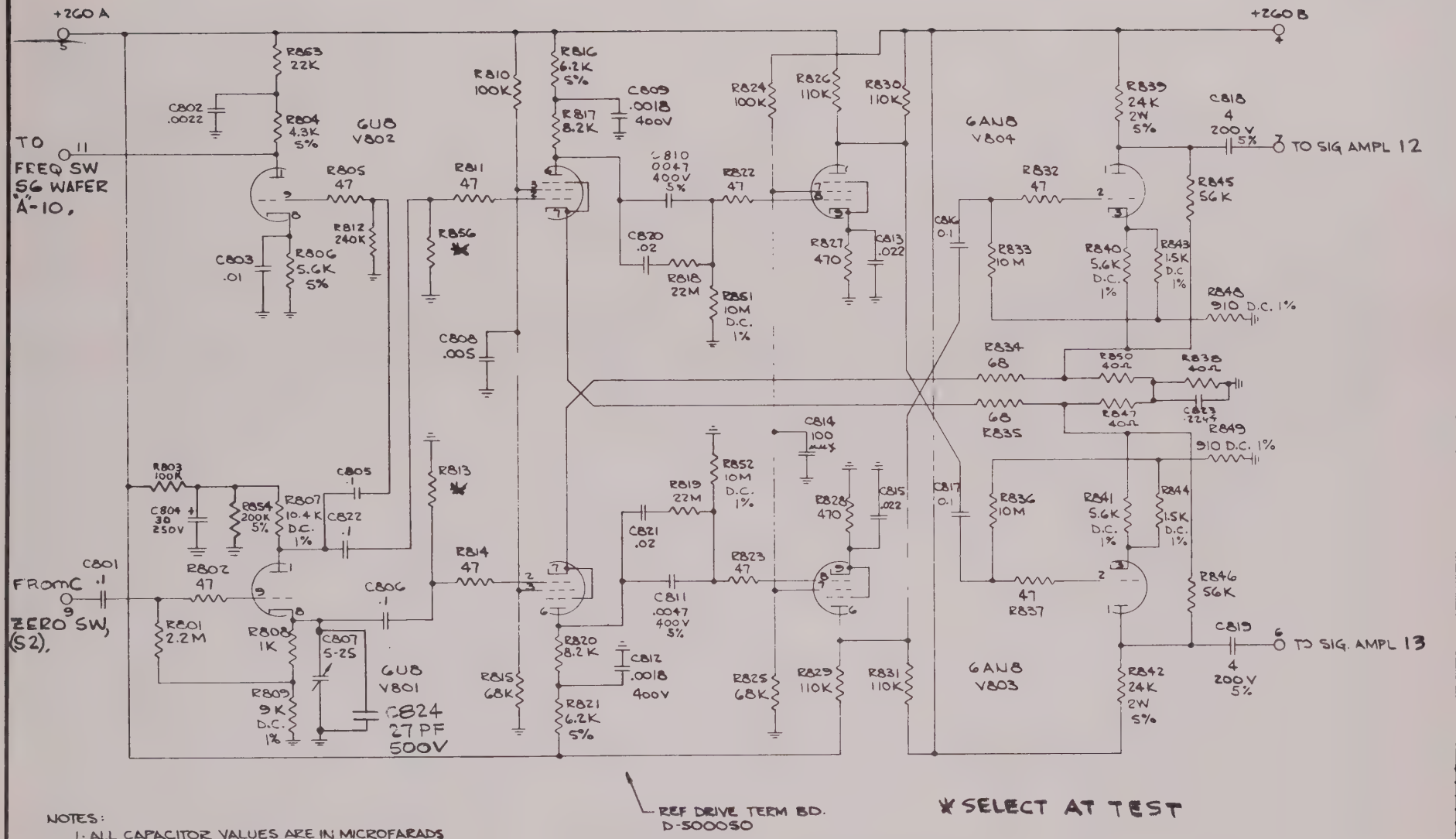
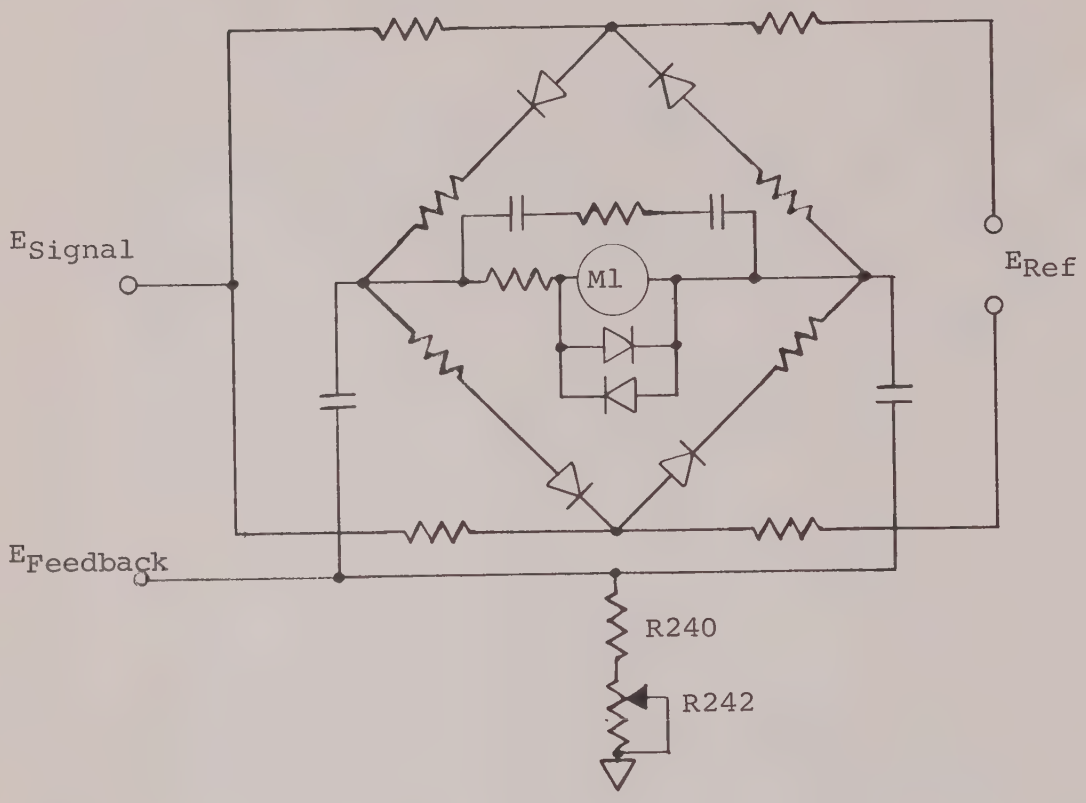


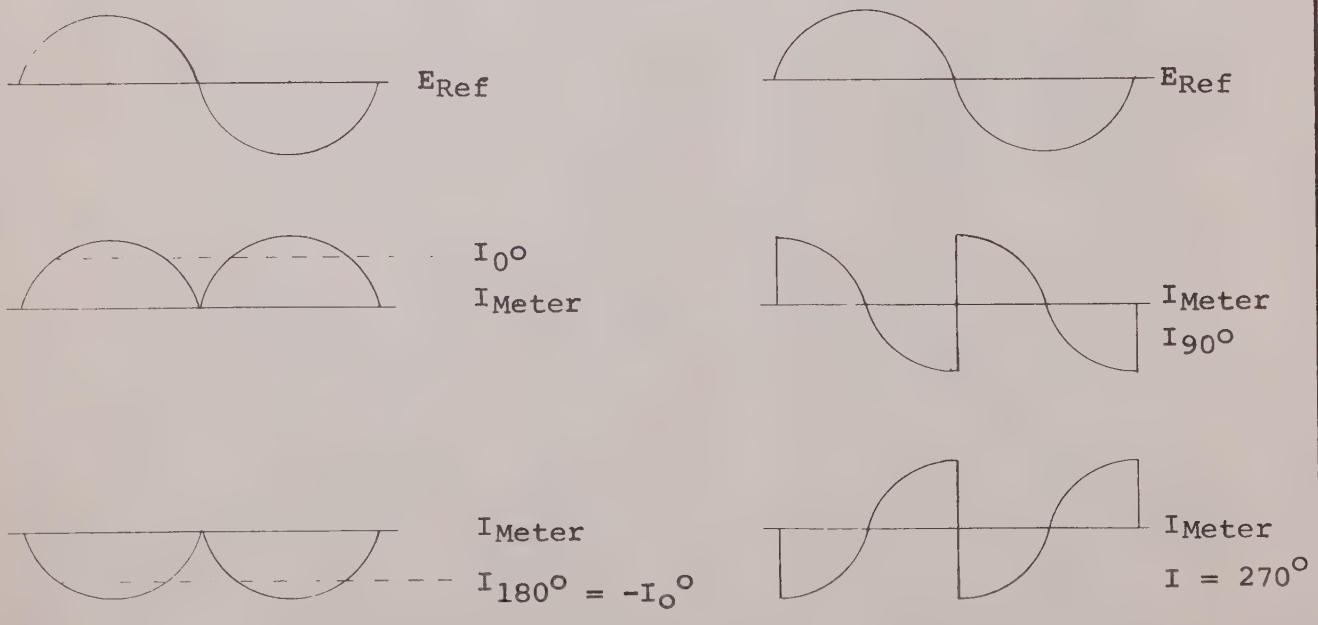
NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½W, ±10% UNLESS OTHERWISE SPECIFIED
3. GRD PIN NO.'S 1, 8 & 10
4. SEE PAGE 5.2 FOR D.C. VOLTAGES

REFERENCE DRIVER AMPLIFIER

FIGURE 3.8

SIMPLIFIED PHASE SENSITIVE DEMODULATOR





IN PHASE (0°/180°)
(A)

QUADRATURE (90°/270°)
(B)

Figure 3.9

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The response of the phase sensitive detector is limited to signals at the reference frequency as well as to odd order harmonics. All other frequencies are rejected, except for signals very near the reference frequency. Here, the meter movement will oscillate between plus and minus maximums at a rate equivalent to the difference between the signal frequency and the reference frequency. Response for this type detector to odd-order harmonics will never be greater than the fundamental response multiplied by a factor of 1/n where "n" is the order of the harmonic. In fact, it will usually be less and dependent upon of the phase relation of the harmonic to the reference signal.

The effect of harmonics in the Reference Channel are of a different nature than of the Signal Channel. The resultant errors are due to shifts in the point at which the diodes start to conduct. Hence, second harmonic distortion can cause errors if the zero crossover of the second harmonic is not coincident with that of the fundamental. The most significant errors due to second and even order harmonic occur when the harmonic signals are present in both channels in phase with each other, and the harmonic phase are such that they peak when the fundamental is at zero crossing. Further, this error occurs when the two channels are in quadrature relationship with each other and may be expressed as:

$\theta E_M = 2K_S K_R \times 57.3$

θE_M = Maximum angular error in degrees of Phase Dial.

K_S = Ratio of 2nd harmonic to Fundamental in the Signal Channel ($K_S \times 100$ = % distortion).

K_R = Ratio of 2nd harmonic to Fundamental in the Reference Channel ($K_R \times 100$ = % distortion).

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For example, if 3% second harmonic distortion were present in both inputs in the most adverse phase relationship, the error would be 0.12^{o}. It is noted that errors due to second harmonic in the Reference Channel only are small and may be generally neglected except for very large values of distortion.

Third harmonics in the Reference Channel only may cause an error of K_R x 57.3 degrees in the relative phase of the reference if the harmonic peak when the fundamental is at zero crossing. For 3% distortion of this nature, an error of 1.7^{o} may result in Phase Dial reading.

In order to eliminate many of the above errors, when making accurate phase measurements, it is recommended that signal and reference filters be used.

Where a Signal Channel filter is used, there is, of course, essentially no response to harmonics in the Signal Channel.

When used as a conventional voltmeter, the phase-sensitive rectifier is switched to a full wave rectifier configuration. Operation is identical to that of a full wave bridge power supply in which the meter movement acts as the load.

Effects of Distortion

The current through the meter in the latter circuit is proportional to the average value of the voltage waveform applied. Calibration of the meter in RMS is based on a ratio between the average and effective values of a true sinesoidal voltage. Deviation from a true sinewave may cause errors in the meter indication. The Table lists the range of possible errors due to the 2nd and 3rd harmonic distortion.

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TABLE - Errors Due to Harmonics in a Typical Average Detector

Harmonic Order	Harmonic Content	Error
2nd	10%	Nil
2nd	20%	0 to +2%
2nd	50%	0 to +10%
3rd	10%	-4% to +4%
3rd	20%	-6% to +8%
3rd	50%	-10% to +16%

POWER SUPPLY

A special power supply is used in the VM-301A which meets the needs of the various amplifiers and circuitry throughout the unit. The particular voltages and regulation characteristics are specifically designed for use in the instrument. The schematic of Figure 3.10 shows its detail.

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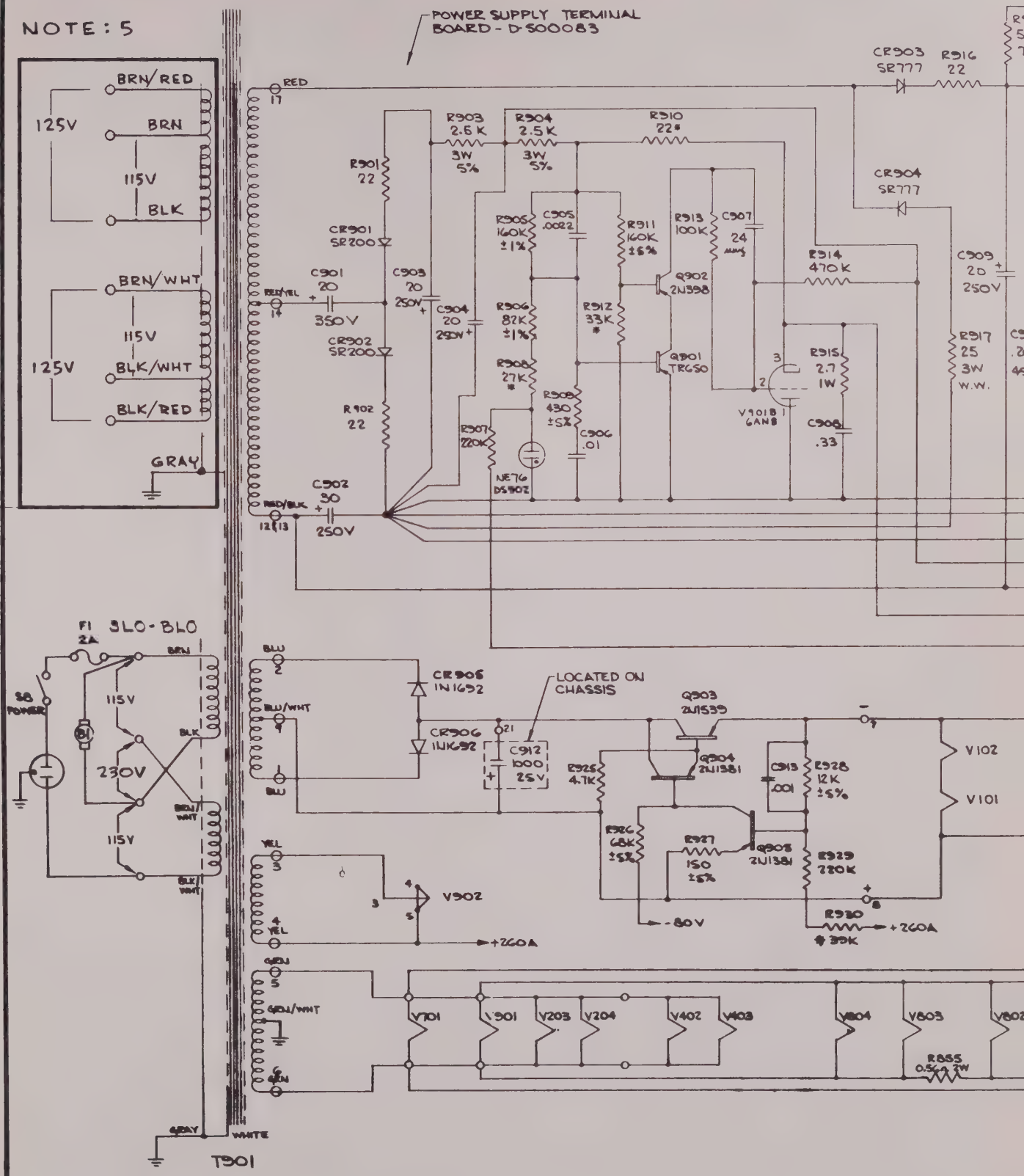
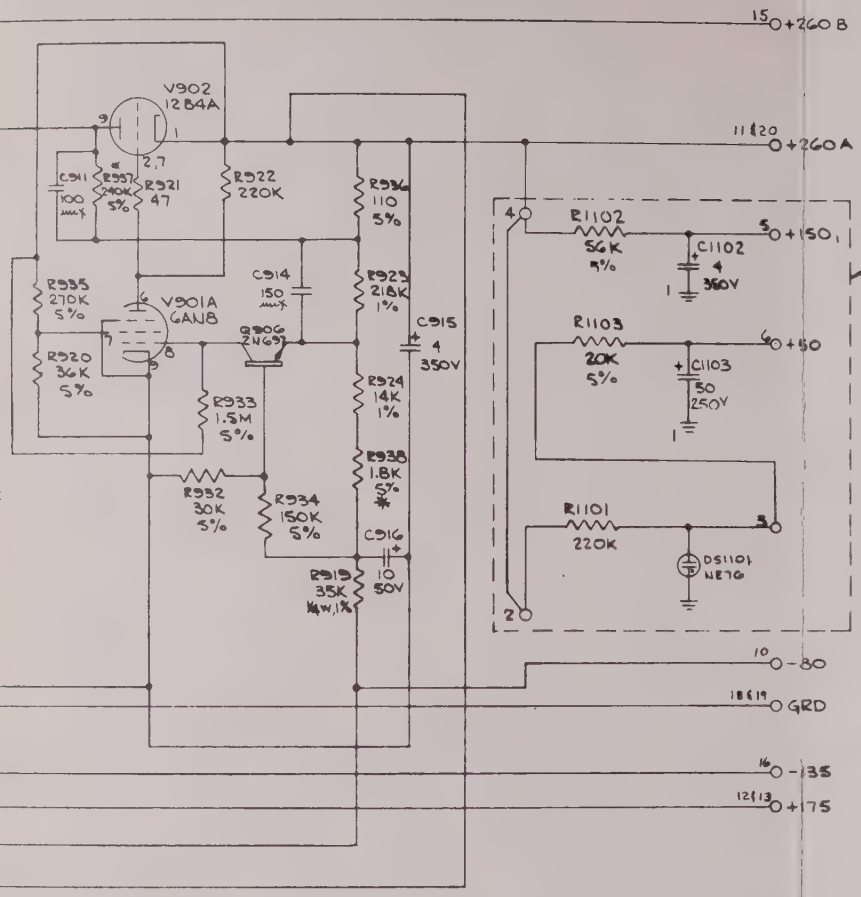
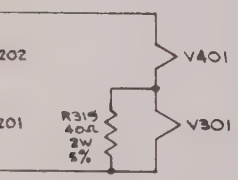
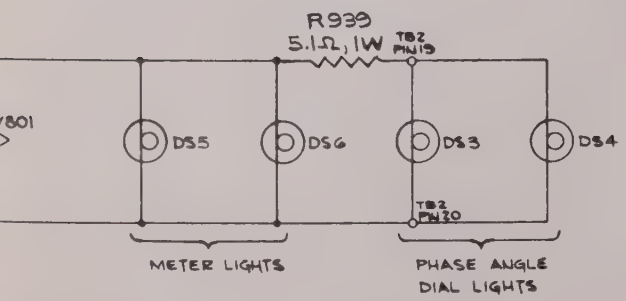

NOTE: 5
POWER SUPPLY TERMINAL BOARD - D500083
BRN/RED
BRN
BLK
BRN/WHT
BLK/WHT
BLK/RED
GRAY
125V
115V
RED
RED/YEL
RED/BLK
CR903 SR777
R916 22
R903 2.6K 3W 5%
R904 2.5K 3W 5%
R910 22Ω
R901 22
CR901 SR200
CR902 SR200
R902 22
C901 20 350V
C903 20 250V
C904 20 250V
R905 160K ±1%
R906 82K ±1%
R907 220K
R908 27K Ω
R909 430 ±5%
C905 .0022
C906 .01
R911 160K ±5%
R912 33K Ω
R913 100K
C907 24 MMF
Q902 2N398
Q901 TRG50
CR904 SR777
R914 470K
C909 20 250V
R915 2.7 1W
V901B 6AN8
C908 .33
R917 25 3W W.W.
NE76 DS902
C902 30 250V
FI 3LO-BLO 2A
SB POWER
BLU
BLU/WHT
CR905 IN1692
CR906 IN1692
LOCATED ON CHASSIS
C912 1000 25V
Q903 2N1539
Q904 2N1381
R925 4.7K
R926 68K ±5%
R927 150 ±5%
Q905 2N1381
C913 .001
R928 12K ±5%
R929 220K
R930 39K
-80V
+260A
V102
V101
YEL
V902
GRN
GRN/WHT
V701
V901
V203
V204
V402
V403
V804
V803
V802
R855 0.5Ω 2W
GRAY
WHITE
T901



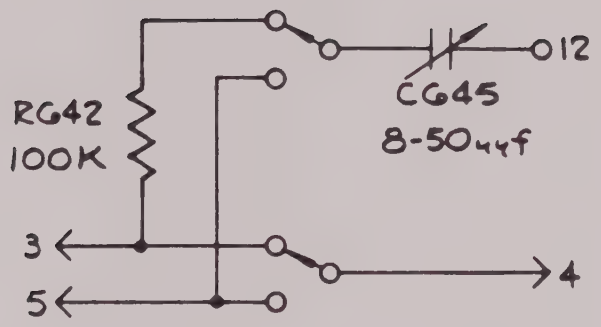




NOTES:

1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½W, ±10% UNLESS OTHERWISE SPECIFIED
3. C901, 902, 903, 909 & 912 ARE USED AS INPUT CAPACITORS WITH SILICON RECTIFIER
4. SEE PAGE 5.2 FOR D.C. VOLTAGES
5. SOME INSTRUMENTS ARE EQUIPPED WITH ALTERNATE PRIMARY. SEE FIG. 2-1 FOR CONNECTION INFORMATION.

POWER SUPPLY
FIGURE 3.10
Page 3.20



FREQUENCY SWITCH (S6)
WAFER "A"
FIGURE 3.11

A-760562

FREQUENCY SWITCH (S6) INTERCONNECTIONS

Pin #	Connects To	Pin #	Connects To
Bd-1- 1	Pin 64(S6)	39	Pin 10(S6)
2	R505-1(cw)	40	Pin 75(S6)
3	Pin 42(S6)	41	TB6-P
4	Pin 45(S6)	42	Pin 3(S6)
5	TB5-8	43	T602-1
6	Pin 70(S6)	44	T602-3
7	T601-6	45	Pin 4(S6)
8		46	Pin 60(S6)
9	S4 B9R	47	Pin 53(S6)
10	Pin 39(S6)	48	Pin 73(S6)
11	TB6-A	49	
12	TB6-B	50	Pin 59(S6)
13	R633-2		
14	R633-3		
15	TB6-D	BD-3-51	
16	TB6-C		
17		52	S4B9F
18	S4 A9R	53	Pin 47(S6)
19	R505-2	54	S7-NC
20	Ref Pre Amp Pin 1	55	Pin 38(S6)
21	TB5-13	56	T601-4
22		57	T602-4
23	R505-3(ccw)	58	S4-A9F
24	S4 B12F	59	Pin 50 (S6)
25	Pin 32(S6)	60	Pin 46 (S6)
		61	S4 B4R
BD-2 -26	Pin 65 (S6)	62	S4 A4R
27		63	
28		64	Pin 1(S6)
29		65	Pin 26(S6)
30		66	
31		67	
32	Pin 25(S6)	68	
33		69	T602-6
34		70	Pin 6(S6)
35	T601-1	71	Pin 40(S6)
36	T601-3	72	
37	TB6-Q	73	Pin 48(S6)
38	Pin 55(S6)	74	
		75	T601-5

Wafer "A"

Term.	Connects To
3	R644A-2
4	S2-NC
5	R644B-2
10	Ref Drive Amp 11

NOTE: Switch Code

B	4	R
Wafer	Term.	Rear

B	9	F
Wafer	Term.	Front

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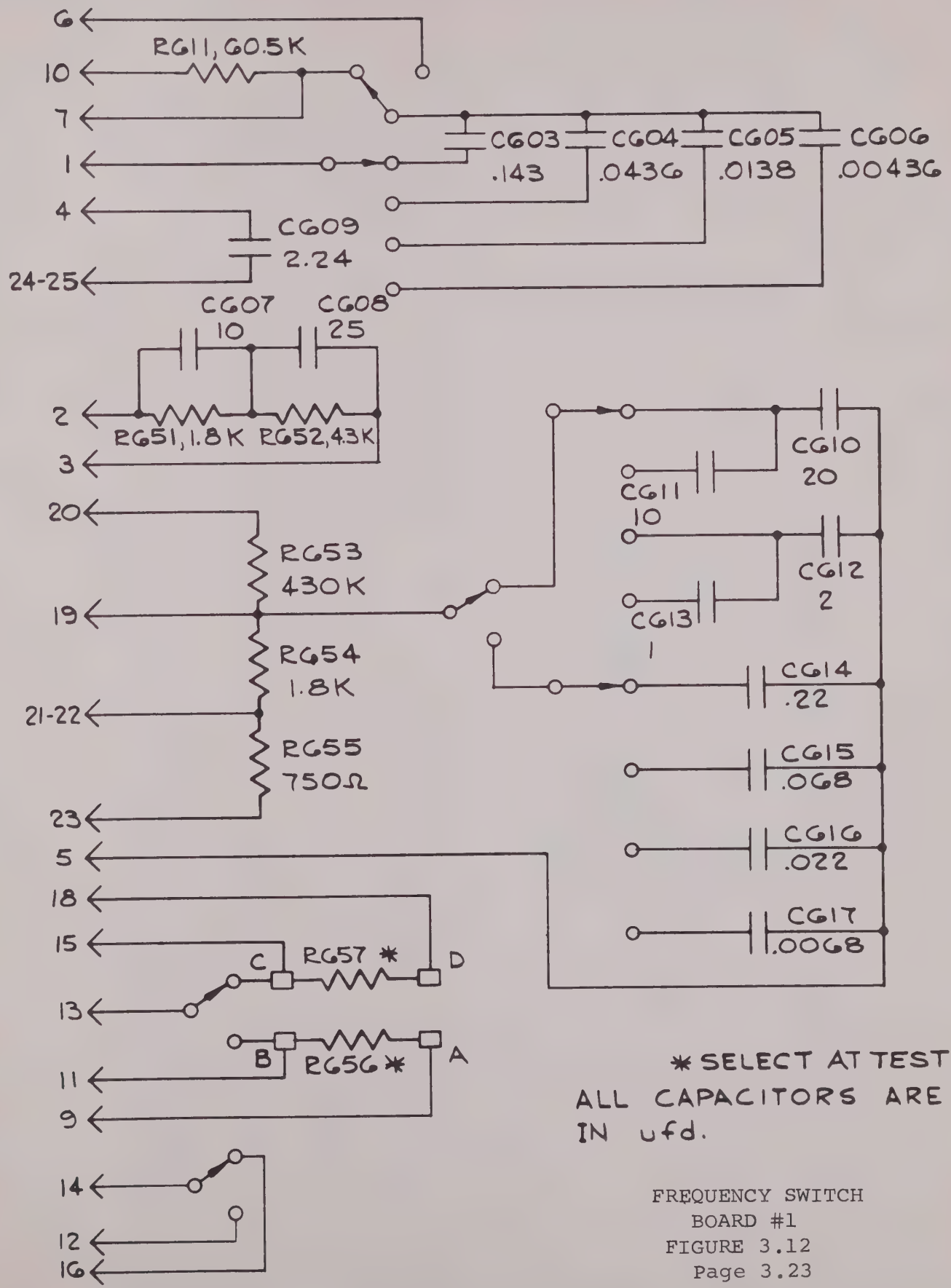
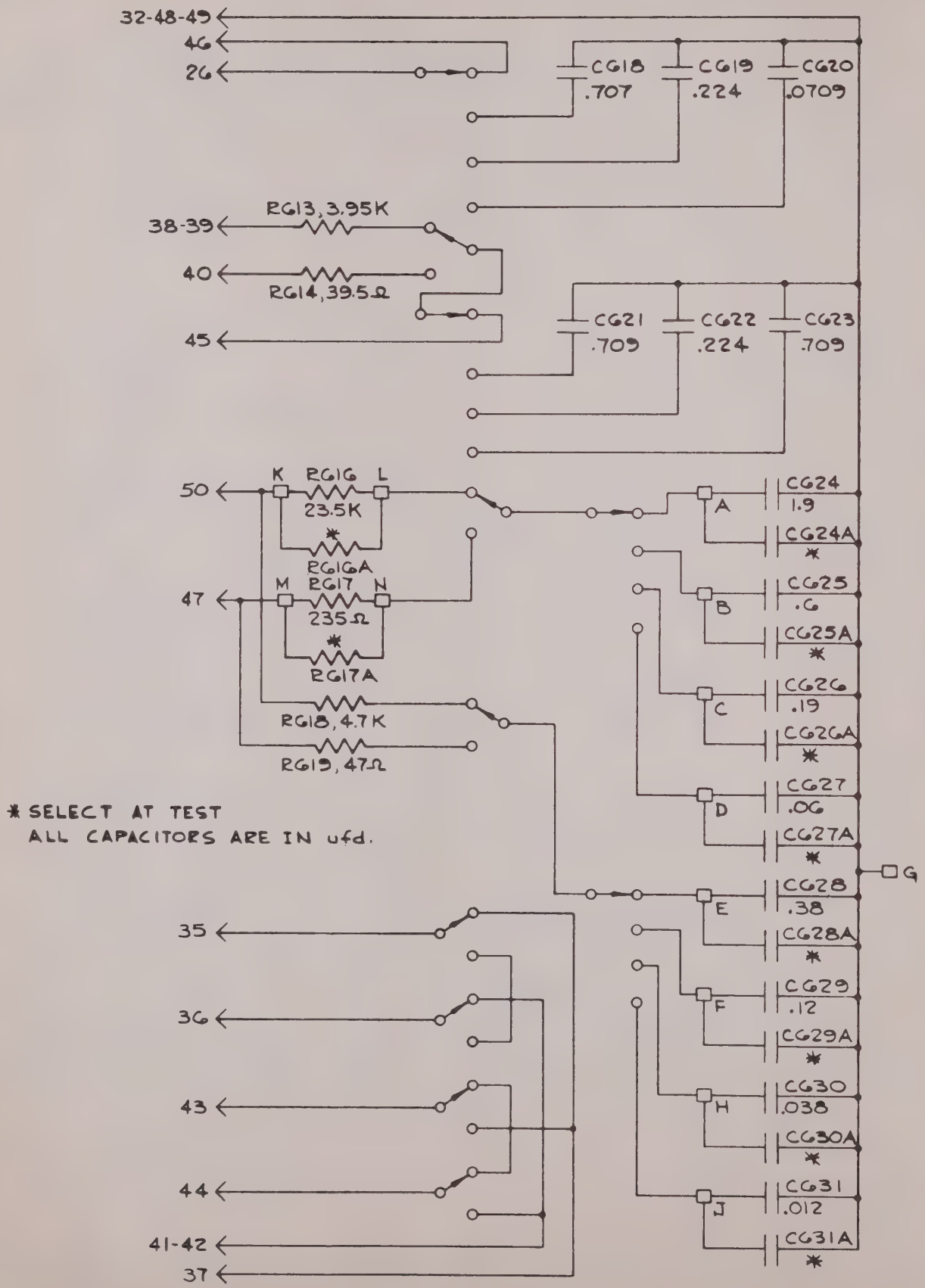
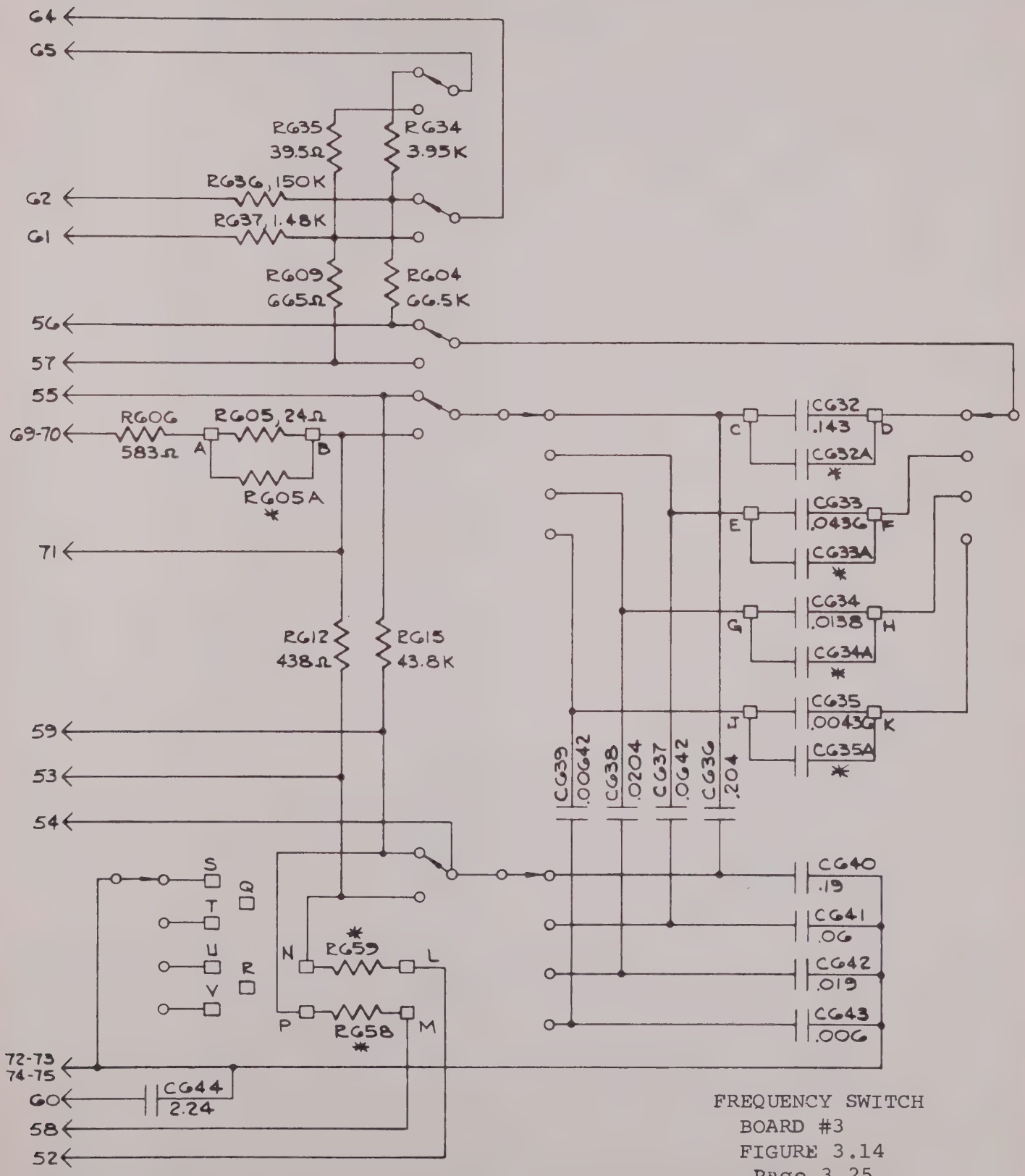


* SELECT AT TEST
ALL CAPACITORS ARE
IN ufd.

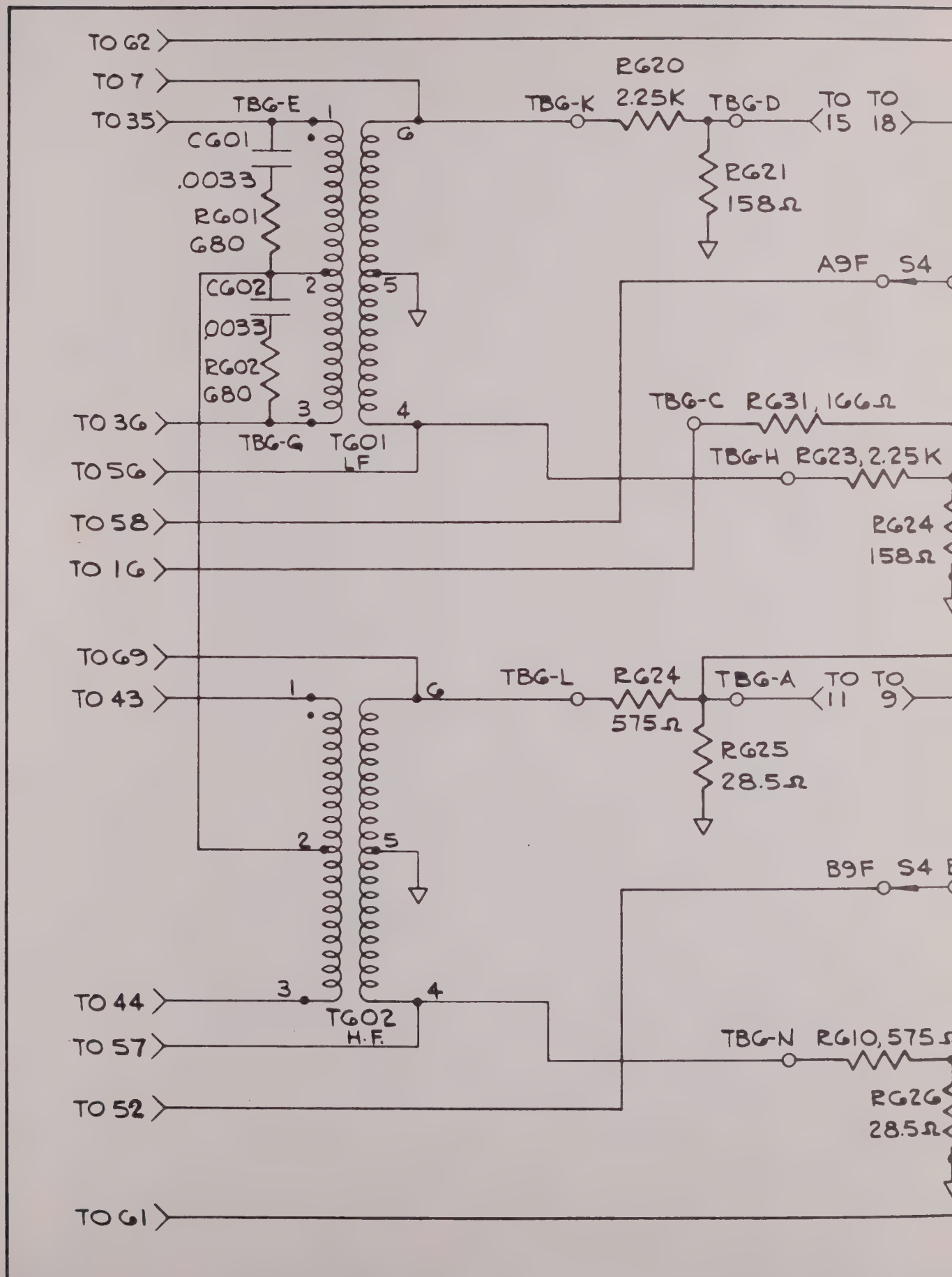
FREQUENCY SWITCH
BOARD #1
FIGURE 3.12



FREQUENCY SWITCH - BOARD #2
FIGURE 3.13
Page 3.24



FREQUENCY SWITCH
BOARD #3
FIGURE 3.14


TO G2
TO 7
TO 35
TBG-E
1
CG01
.0033
RG01
680
CG02
2
.0033
RG02
680
3
TO 36
TO 56
TO 58
TO 16
TBG-G
TG01
LF
4
5
6
RG20
2.25K
TBG-K
TBG-D
TO TO
15 18
RG21
158Ω
A9F S4
TBG-C RG31, 166Ω
TBG-H RG23, 2.25K
RG24
158Ω
TO 69
TO 43
TBG-L
RG24
575Ω
TBG-A
TO TO
11 9
RG25
28.5Ω
B9F S4
TO 44
TO 57
TO 52
TG02
H.F.
TBG-N RG10, 575Ω
RG26
28.5Ω
TO G1

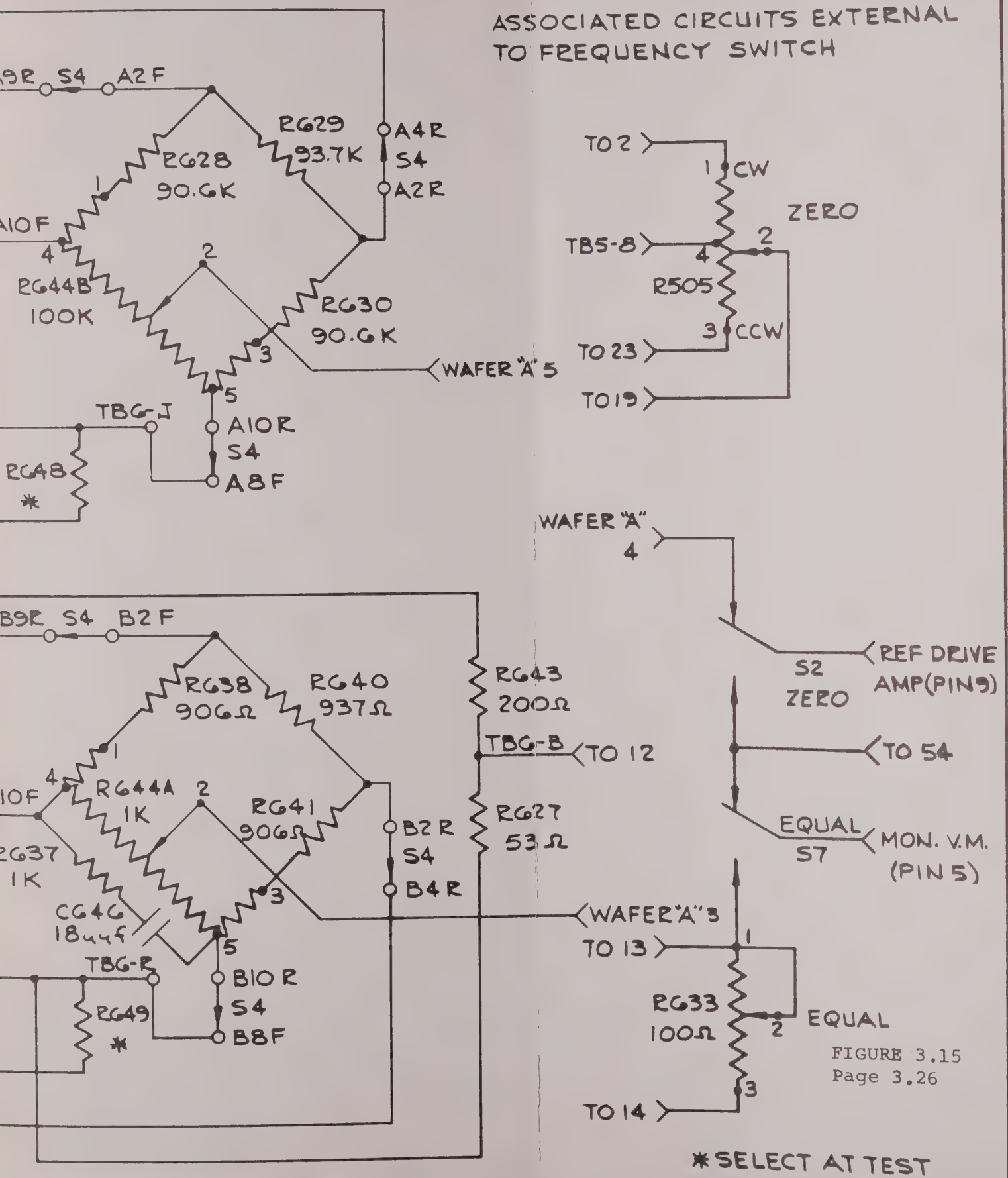


FIGURE 3.15
Page 3.26

SECTION IV

MAINTENANCE

The following section contains instructions for the general maintenance of the Phase Angle Voltmeter. Detailed alignment procedures are described in Section VII. It is recommended that alignment procedures be followed only if proper test equipment and sufficiently skilled personnel are available to perform the work.

CAUTION: High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration or setting up of the instrument.

COVER REMOVAL

A. Top and bottom covers are held in place by five screws each, and side covers are held in place by four screws each. Remove any set of these screws to allow removal of the corresponding top, bottom, or side covers.

B. To remove the back cover, remove the four screws at the sides of the back cover. For complete removal the fan mounting must be removed from the back panel itself.

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TUBE REPLACEMENT

CAUTION: DO NOT REMOVE TUBES FROM THE VOLTMETER BEFORE REMOVING POWER.

A. With the exception of V201 and V301, no circuit in the VM-301A is critical to tube replacement. However, for maximum accuracy the calibrations (as described in Section VII) should be checked following tube changing.

B. When replacing V201, it will be necessary to monitor the plate voltage of V202. This is at the top of R212 (5.6K, 1/2W Resistor) located directly under the V202 tube socket on the 500047 (Signal Amplifier) components board (Figure 4.2). A V201 (6BH6) tube should be chosen so that this voltage will be 150 ± 5 volts to ground, or trim R207 for 150 ± 5 volts after selecting a tube that will result in a voltage close to 150V.

C. When replacing V301, adjust DC voltage on Pin 16 of 500086 (Reference Pre-Amplifier) to equal zero with R309.

NOTE: Before changing the settings of any of the internal adjustments, check that the tubes are good.

REPLACEMENT OF PARTS

A. To remove and replace any of the tubes, it is necessary to remove the top or back covers of the instrument.

B. Most trouble shooting can be done by removing the top, bottom, and back covers. If it is desirable to inspect the boards mounted on the inside of the rear board panel or the terminal boards located under the power transformers, the inside rear panel may be dropped to a horizontal position. To accomplish this, first remove the two side covers. The screws at the top on either side of the inside rear panel must then be removed and the two screws at the bottom must be loosened.

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C. Although any component may easily be changed with the boards in place, should it be desirable to remove a board, remove the proper screws from the front of the board and unsolder the wires on the terminal lugs.

D. Several resistors in the voltmeter are precision components. If these resistors require replacement, use the same value and type as the original. If different values are used to components are moved, calibration or frequency response may be affected and readjustment may be required. Be careful to replace components as closely as possible in the same position the original components occupied. Pay careful attention to wiring and do not reroute or move any of the wires.

E. Transistors and semiconductor diodes are used throughout the instrument in the amplifiers, power supply, and meter circuit. If replacement is necessary, standard semiconductor practices are necessary. If any of the diodes in the meter circuits (CR204, CR205, CR206, CR207) are replaced, the voltmeter calibration, frequency, and phase calibration should be checked.

F. Panel lights in the meter are removable from the rear of the meter. They are made accessible by opening the meter door. The cap of the meter light assembly snaps into the knurled portion of the assembly. Do not attempt to remove the entire light assembly.

G. In the event it becomes necessary to replace the Phase Dial lights, see Figure 4.12 for replacement instructions.

H. The Phase Dial of the VM-301A is driven indirectly by means of a dial cord. If the dial cord requires replacement, see Figure 4.12.

J. In the rare case where the Phase Dial must be removed or replaced, it should be done in the following manner:

1. Remove front panel.
2. Remove dial cord, indicator bracket and lamp bracket.

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3. Remove dial from pot shaft by loosening the set screws which hold it.
4. Replace dial on shaft (set screw should be tightened lightly at this point as the dial must be aligned with pot).
5. Replace indicator bracket, lamp bracket, and dial cord (see Figure 4.19).
6. Dial must now be aligned with pot (see Phase Dial Alignment, Page 5.20).
7. Replace front panel.

K. The FREQUENCY Switch mechanism is described in Figure 4.12, and the instructions should be followed if it is disassembled.

REFERENCE LEVEL METER REPLACEMENT

A. Remove top and left side covers.

B. Remove 2 flat head screws, which hold flat top plate, from top of sub-panel.

C. Remove screws holding left end of flat plate from left side of instrument.

D. Remove Reference Meter mounting screws (top of meter).

E. Meter may now be lifted from its mount and leads disconnected.

F. Replace meter by following above instructions in reverse order, being careful to reconnect leads to same terminals.

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REPLACEMENT PARTS LIST

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Pre-Amplifier (Fig. 4.1)	500620	
C101	Capacitor, Fixed 10 ufd - 50V	802209	
C102	Capacitor, Variable 5-18 uufd	802547	
C103	Capacitor, Fixed .1 ufd - 200V	802220	
C104	Capacitor, Fixed 10uufd-500V ±10%	802422	
R101, 106	Resistor, Fixed, Comp. 24K-1/2W ±5%	800518	
R102	Resistor, Fixed, Comp. 47Ω-1/2W ±10%	800991	
R103	Resistor, Fixed D.C. 2.1K-1/2W ±1%	803065	
R104, 105	Resistor, Fixed, Comp. 20M-1/2W ±5%	801482	
V101, V102	Tube, Electron 6AB4	801070	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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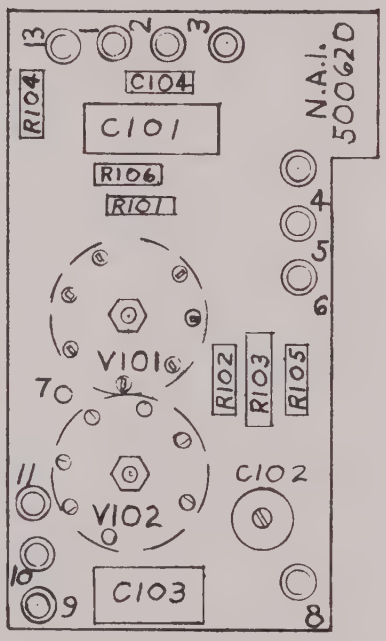

SIGNAL PREAMPLIFIER BOARD ASS'Y
#500620
Figure 4.1

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Signal Amplifier (Fig. 4.2)	D500047	
C201	Capacitor, Fixed, 4ufd, 350V	800888	
C202	Capacitor, Fixed, .0033ufd, 400V, ±10%	802265	
C203	Capacitor, Fixed, 15uufd, 500V, ±10%	801743	
C204	Capacitor, Fixed, 80ufd,150V	801266	
C205	Capacitor, Fixed, .0018ufd, 400V, ±10%	802236	
C206	Capacitor, Fixed, .056ufd, 200V, ±10%	802222	
C207	Capacitor, Fixed, .047ufd,400V, ±10%	802395	
C208	Capacitor, Fixed, .01ufd,400V, ±10%	802237	
C209	Capacitor, Fixed, .022ufd,200V, ±10%	802219	
C210	Capacitor, Fixed, 620uufd, 300V, ±10%	801746	
C211	Capacitor, Fixed, 47uufd,500V, ±10%	801747	
C212	Capacitor, Fixed,.01ufd,200V, ±10%	801879	
C213	Capacitor, Variable, 5-25uufd	801483	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Signal Amplifier (Fig. 4.2)	D500047	
C214	Capacitor, Fixed, 240uufd, 500V, ±10%	801744	
C215	Capacitor, Fixed, .0047ufd, 400V, ±10%	802238	
C216	Capacitor, Fixed, 10ufd, 25V	801539	
C217,C218	Capacitor, Fixed, .47ufd, 400V, ±10%	800025	
C219	Capacitor, Fixed, 750uufd, 300V, ±5%	802315	
C220	Capacitor, Fixed, 33uufd, 500V, ±10%	801749	
C221	Capacitor, Fixed, .1uf, 200V	802220	
CR204,205, 206,207	Diode IN309	802924	Fairchild
L201,L202	Choke 6.8uh	801742	
R201,209,219 230,241	Resistor, Fixed, Comp.,47Ω, 1/2W, ±10%	800991	
R202	Resistor, Fixed, Comp., 150K, 1/2W, ±10%	800057	
R203	Resistor, Fixed, Comp., 120K, 1/2W, ±5%	800869	
R204	Resistor, Fixed, Comp., 33K, 1/2W, ±10%	800839	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Amplifier (Fig. 4.2)	D500047	
R205	Resistor, Fixed, Dep. Carb., 100Ω, 1/2W, ±1%	801592	
R206	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R207	Resistor, Fixed, Comp., 470K, 1/2W, ±10%	800060	
R208	Resistor, Fixed, Comp., 3K, 1/2W, ±5%	800615	
R210, 214, 216	Resistor, Fixed, Comp., 39K, 1/2W, ±10%	801069	
R211	Resistor, Fixed, Comp., 47K 1/2W, ±10%	800087	
R212	Resistor, Fixed, Comp., 5.6K, 1/2W, ±5%	8000641	
R213, 231	Resistor, Fixed, Comp., 11K, 1/2W, ±5%	800620	
R215	Resistor, Fixed, Comp., 4.3M, 1/2W, ±5%	803707	
R217	Resistor, Fixed, Comp., 6.2M 1/2W, ±5%	803708	
R218	Resistor, Fixed, Comp., 270K, 1/2W, ±10%	800059	
R220	Resistor, Fixed, Comp., 68K 1/2W, ±5%	800528	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Amplifier (Fig. 4.2)	D500047	
R221	Resistor, Fixed, Comp., 47K 1/2W, ±10%	800078	
R222	Resistor, Fixed, Comp., 820K, 1/2W, ±10%	801598	
R223	Resistor, Fixed, Dep. Carb., 499K, 1/2W, ±1%	801597	
R224	Resistor, Fixed, Dep. Carb., 365K, 1/2W, ±1%	801596	
R225	Resistor, Fixed, Comp., 75K, 1/2W, ±5%	800090	
R226	Resistor, Fixed, Comp., 33K, 1W, ±10%	802260	
R227	Resistor, Fixed, Comp., 1.1K, 1/2W, ±5%	801595	
R228	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	
R229	Resistor, Fixed, Comp., 1M, 1/2W, ±10%	800063	
R232	Resistor, Fixed, Dep. Carb., 1K, 1/2W, ±1%	801136	
R233, 236, 237, 238	Resistor, Fixed, Comp., 510Ω, 1/2W, ±5%	800525	
R234, 235	Resistor, Fixed, Dep. Carb., 6.8K, 1/4W, ±0.25%	802802	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

REPLACEMENT PARTS LIST

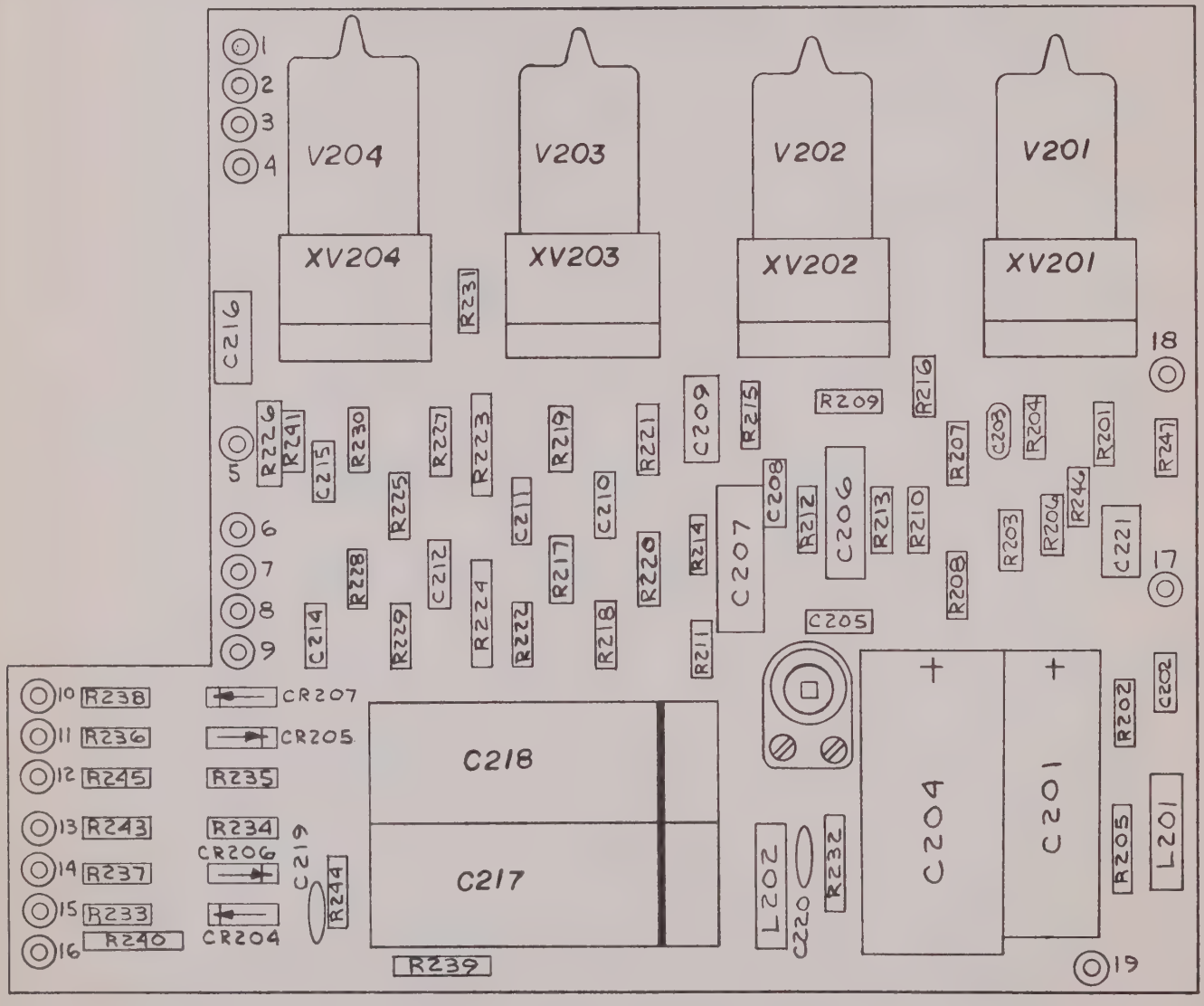
(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
	Assembly, Signal Amplifier (Fig. 4.2)	D500047	
R239	Resistor, Fixed, Dep. Carb., 140Ω, 1/2W, ±1%	802376	
R240	Resistor, Fixed, Dep. Carb., 220Ω, 1/2W, ±1%	801591	
R243, 245	Resistor, Fixed, Comp., 1K, 1/2W, ±10%	800166	
R244	Resistor, Fixed, Comp., 820Ω, 1/2W, ±10%	800082	
R246	Resistor, Fixed, Comp., 100Ω, 1/2W, ±5%	800631	
R247	Resistor, Fixed, Comp., 20Meg, 1/2W, ±5%	801482	
V201, 202 203	Tube 6BH6	802285	
V204	Tube 6U8A	800028	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600



SIG. AMPL. BOARD ASSY.
500047

FIGURE 4.2

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Reference Pre-Amplifier(Fig. 4.3)	D500086	
C301	Capacitor, Fixed, .1ufd, 1000V, ±10%	801068	
C302	Capacitor, Fixed, 300MMF, 500V, ±10%	802342	Special
C303	Capacitor, Fixed, 10uufd, 500V ±5%	802561	Special
C304	Capacitor, Fixed, 12ufd, 350V	801023	
C305	Capacitor, Fixed, 1ufd, 200V, ±5%	802794	
C307	Capacitor, Fixed, 20uuf, 500V, ±5%	802638	
C308, 318	Capacitor, Variable,8-50uufd	800854	Special
C309,311	Capacitor, Fixed, 20ufd, 350V	800847	
C310	Capacitor, Fixed, 24uufd, 500V, ±5%	802170	
C312	Capacitor, Fixed, .1ufd, 400V, ±20%	800020	
C319	Capacitor, Fixed, 250uufd, 500V, ±5%	802310	
R301	Resistor, Fixed, M.F., 10M, 1/2W, ±1%	802864	
R303	Resistor, Fixed, Dep., Carb., 10M, .75W, ±1%	802253	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Reference, Pre-Amplifier (Fig. 4.3)	D500086	
R302	Resistor, Fixed, M.F., 300K, 1/2W, ±1%	802865	
R304	Resistor, Fixed, Comp., 120Ω, 1/2W, ±5%	800407	
R305	Resistor, Fixed, Comp., 16K, 1/2W, ±5%	800619	
R306	Resistor, Fixed, Comp., 360Ω, 1/2W, ±5%	801654	
R307	Resistor, Fixed, Comp., 13K, 1/2W, ±5%	800637	
R308	Resistor, Fixed, M.F, 1M, 1/2W, ±1%	802795	
R309	Resistor, Variable, 10K, 2W, ±10%	801750	
R310	Resistor, Fixed, M.F., 60K, 1/2W, ±1%	802796	
R311	Resistor, Fixed, Comp., 20M, 1/2W, ±5%	801482	
R312	Resistor, Fixed, Comp., 56K, 1/2W, ±10%	800498	
R313	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R314	Resistor, Fixed, Dep. Carb., 10K, 1/2W, ±1%	801481	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

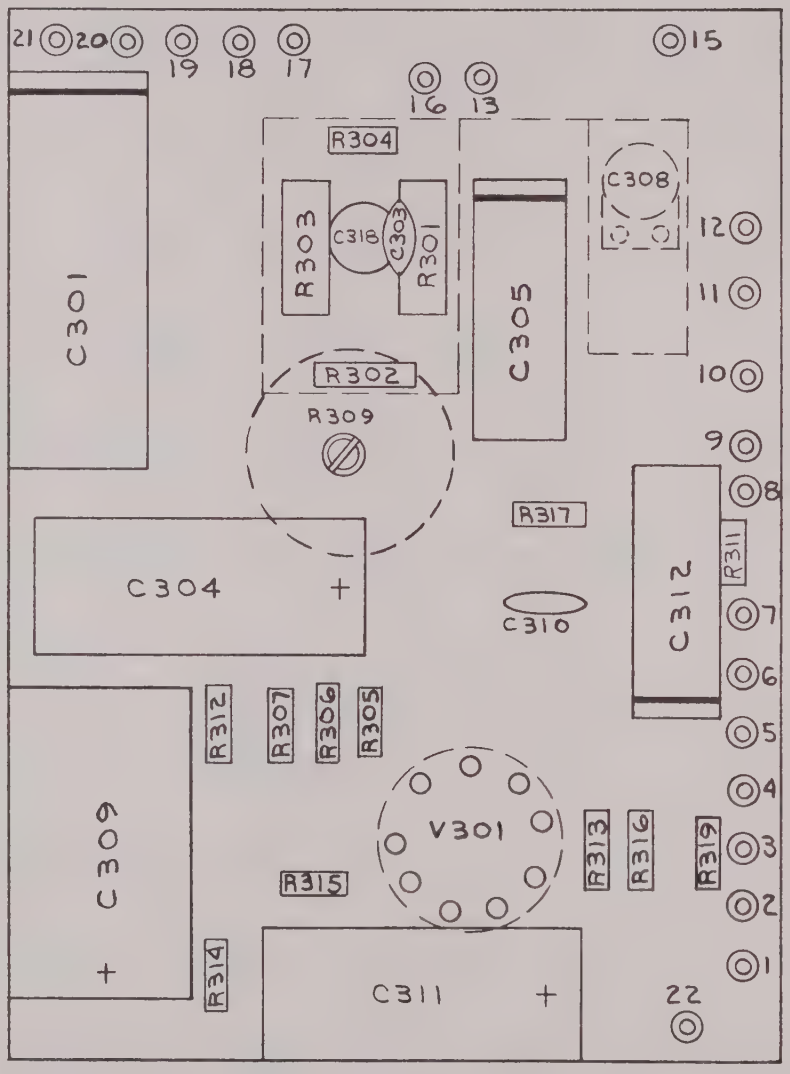
(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
	ASSEMBLY, Reference Pre-Amplifier (Fig. 4.3)	500086	
R315	Resistor, Fixed, Dep. Carb., 4.1K, 1/2W, ±1%	802172	
R316	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R317	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	
R319	Resistor, Fixed, W.W., 40Ω, 2W, ±5%	802328	
V301	Tube, Electron, 12AT7	801019	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600



REF. PRE-AMPL. ASSY.
500086

Figure 4.3

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Reference Amplifier (Fig. 4.4)	D500049	
C401	Capacitor, Fixed, 4ufd, 350V	800888	
C402	Capacitor, Fixed, 680uufd, 300V, ±5%	801787	
C403	Capacitor, Fixed, 820uufd, 500V, ±10%	802344	
C404	Capacitor, Fixed, .0022ufd, 200V, ±10%	802217	
C405,409 410,411	Capacitor, Fixed, .022ufd, 400V, ±10%	802235	
C406	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C407,408	Capacitor, Fixed, .0047ufd, 200V, ±10%	802239	
C412	Capacitor, Fixed, 30ufd, 250V	801528	
CR401, 402	Diode, Silicon, IN658	801661	Clevite
R401,409,413, 416,427,431	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R402,410, 411	Resistor, Fixed, Comp., 68K, 1/2W, ±5%	800528	
R403	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R404,433	Resistor, Fixed, Comp., 1K, 1/2W, ±5%	800414	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC industries, inc.

200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
	ASSEMBLY, Reference Amplifier (Fig. 4.4)	D500049	
R405	Resistor, Fixed, Comp., 47K, 1/2W, ±10%	800087	
R406	Resistor, Fixed, Comp., 3K, 1/2W, ±5%	800615	
R407	Resistor, Fixed, Comp., 390Ω, 1/2W, ±5%	800629	
R408	Resistor, Fixed, Comp., 430Ω, 1/2W, ±5%	800640	
R412	Resistor, Fixed, Comp., 10K, 1/2W, ±10%	800089	
R414,415	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	
R417,420, 424	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	
R418,419	Resistor, Fixed, Comp., 470Ω, 1/2W, ±10%	800084	
R421	Resistor, Fixed, Comp., 130K, 1/2W, ±5%	800806	
R422,423	Resistor, Fixed, Comp., 2.7K, 1/2W, ±5%	800643	
R425	Resistor, Fixed, Comp., 1.5M, 1/2W, ±10%	800378	
R426	Resistor, Fixed, Comp., 150K, 1/2W, ±10%	800057	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

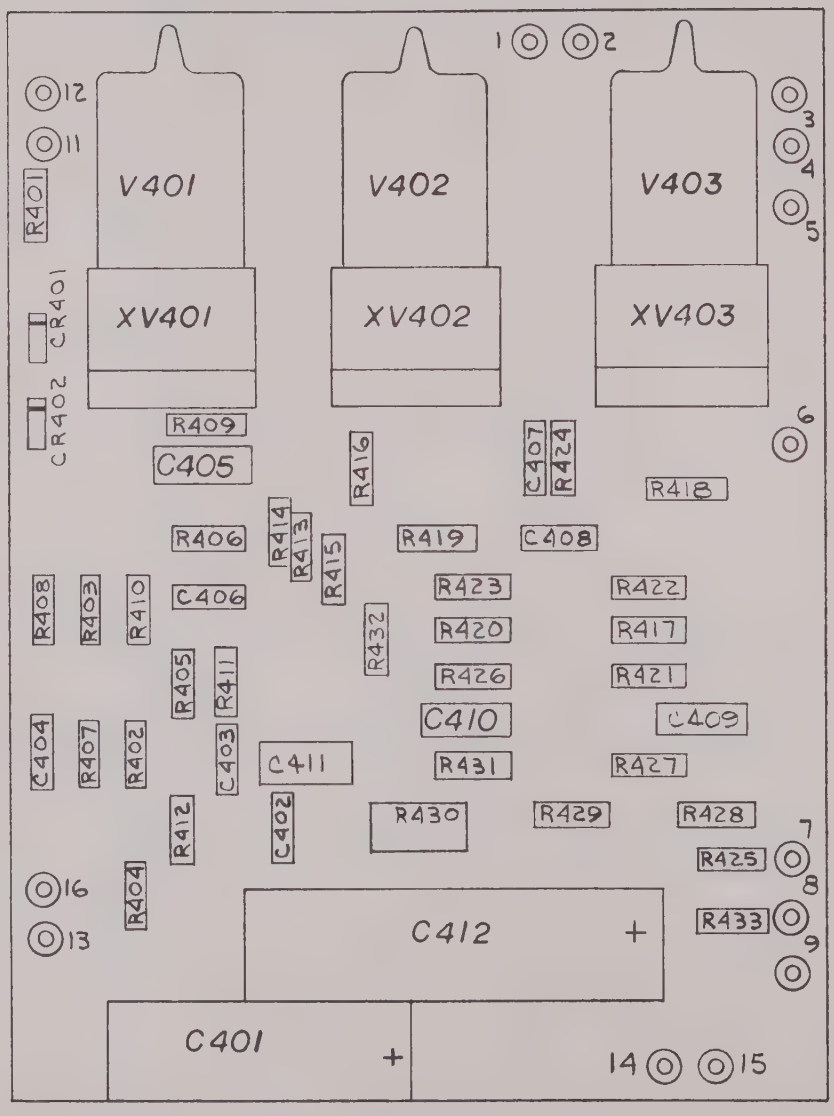
(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Reference Amplifier (Fig. 4.4)	D500049	
R428,429	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R430	Resistor, Fixed, 30K, 2W, ±5%	802828	
R432	Resistor, Fixed, Comp., 200Ω, 1/2W, ±5%	801672	
V401,402,403	Tube, Electron 6U8A	800028	
S4	ASSEMBLY, Function Switch	500625	
R629	Resistor, Fixed, Dep. Carb., 93.7K, 1/2W, ±1%	801622	
R640	Resistor, Fixed, Dep. Carb., 937Ω, 1/4W, ±1%	801621	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600



REF. AMPL. ASSY.
500049

Figure 4.4

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
S6	ASSEMBLY, Frequency Switch	782400	
C645	Capacitor, Variable 8-50MMFD	800854	
R642	Resistor, Fixed, Comp., 100K, 1/2W, ±5%	800520	
	DECK #1 SUB-ASSEMBLY Figures 4.5 and 4.6	500607	
C603	Capacitor, Fixed, .143ufd,100V, ±1%	803619	Special
C604	Capacitor, Fixed, .0436 ufd, 100V, ±1%	803599	Special
C605	Capacitor, Fixed, .0138 ufd, 100V, ±1%	803600	Special
C606	Capacitor, Fixed, .00436ufd, 100V, ±1%	803601	
C607,C611	Capacitor, Fixed, 10ufd, 15V	801550	
C608	Capacitor, Fixed, 25uufd, 600V, ±5%	801543	
C609	Capacitor, Fixed, 2.24ufd, 50V, ±1%	803576	Special
C610	Capacitor, Fixed, 20ufd, 15V	801551	
C612	Capacitor, Fixed, 2ufd, 15V	801549	
C613	Capacitor, Fixed, 1ufd, 15V	801548	
C614	Capacitor, Fixed, .22ufd, 200V, ±10%	802233	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

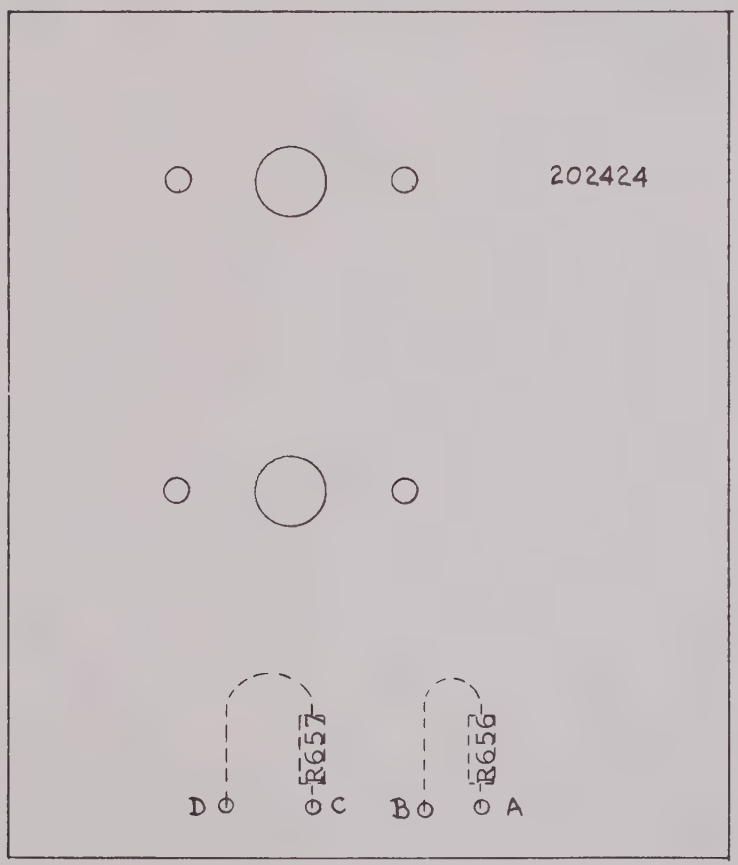
CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
S6	ASSEMBLY, Frequency Switch	782400	
	DECK #1 SUB-ASSEMBLY	500607	
C615	Capacitor, Fixed, .068ufd, 200V, ±10%	802225	
C616	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C617	Capacitor, Fixed, .0068ufd, 200V, ±10%	802224	
R611	Resistor, Fixed, D.C., 60.5K, 1/4W, ±1/2%	802584	
R651, R654	Resistor, Fixed, Comp. 1.8K, 1/2W, ±5%	800858	
R652	Resistor, Fixed, Comp. 4.3K, 1/2W, ±5%	800621	
R653	Resistor, Fixed, Comp. 430K, 1/2W, ±5%	802470	
R655	Resistor, Fixed, Comp. 750Ω, 1/2W, ±5%	800911	
R656, R657	Resistor, Fixed, Comp. (Select at Test)		
	DECK #2 SUB-ASSEMBLY	500608	
C624A-C631A	Capacitor, Fixed (Select at Test)		
C618,C621	Capacitor, Fixed, .709ufd, 100V, ±1%	803587	Special

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600

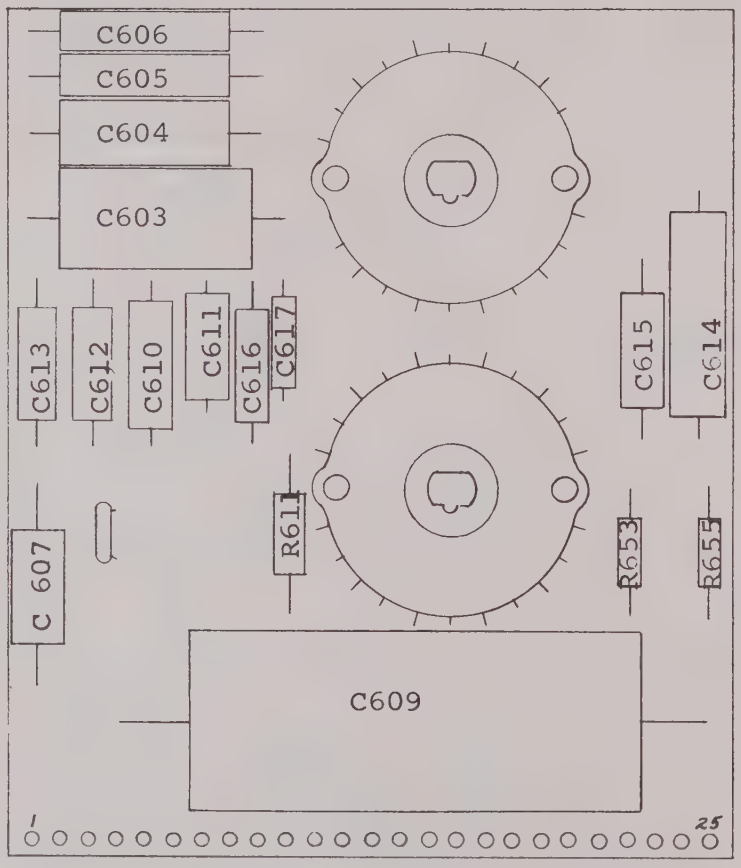
NOTE: Dash line components are select at test.
See Figure Figure 3.12 and Alignment Procedure
of Section V.



REAR
DECK #1

FIGURE 4.5

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600



FRONT
FREQUENCY SWITCH
DECK #1

FIGURE 4.6

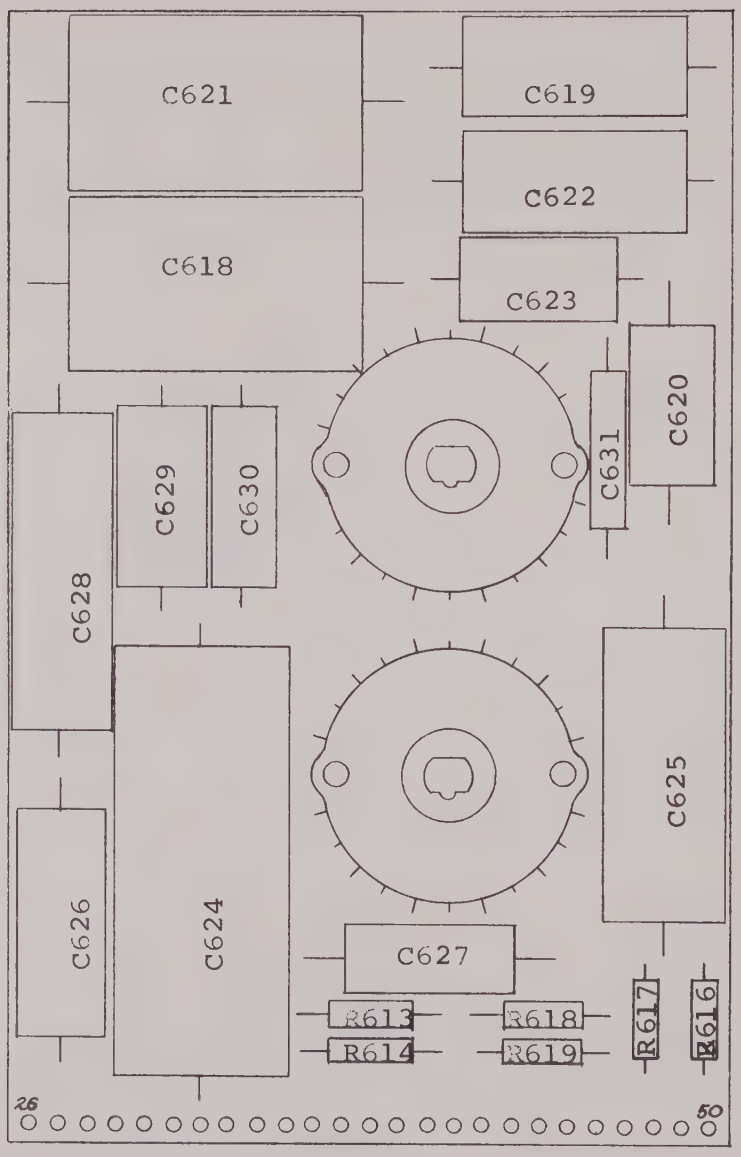
REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	DECK #2 SUB-ASSEMBLY Figures 4.7 & 4.8	500608	
C619,C622	Capacitor, Fixed, .224 ufd, 100V, ±1%	803588	Special
C620,C623	Capacitor, Fixed, .0709ufd, 100V, ±1%	803589	Special
C624	Capacitor, Fixed, 1.9ufd,100V, ±2°	803590	Special
C625	Capacitor, Fixed, .6ufd,100V, ±2%	803591	Special
C626	Capacitor, Fixed, .19ufd, 100V,±2%	803592	Special
C627	Capacitor, Fixed, .06ufd, 100V, ±2%	803593	Special
C628	Capacitor, Fixed, .38ufd, 100V, ±2%	803594	Special
C629	Capacitor, Fixed, .12ufd, 100V, ±2%	803595	Special
C630	Capacitor, Fixed, .038ufd, 100V, ±2%	803596	Special
C631	Capacitor, Fixed, .012ufd, 100V, ±2%	803597	Special
R617A, R616A	Resistor, Fixed(Select at Test)		
R613	Resistor, Fixed, D.C., 3.95K 1/4W, ±1/2%	801705	
R614	Resistor, Fixed, D.C., 39.5Ω, 1/4W, ±1/2%	801692	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

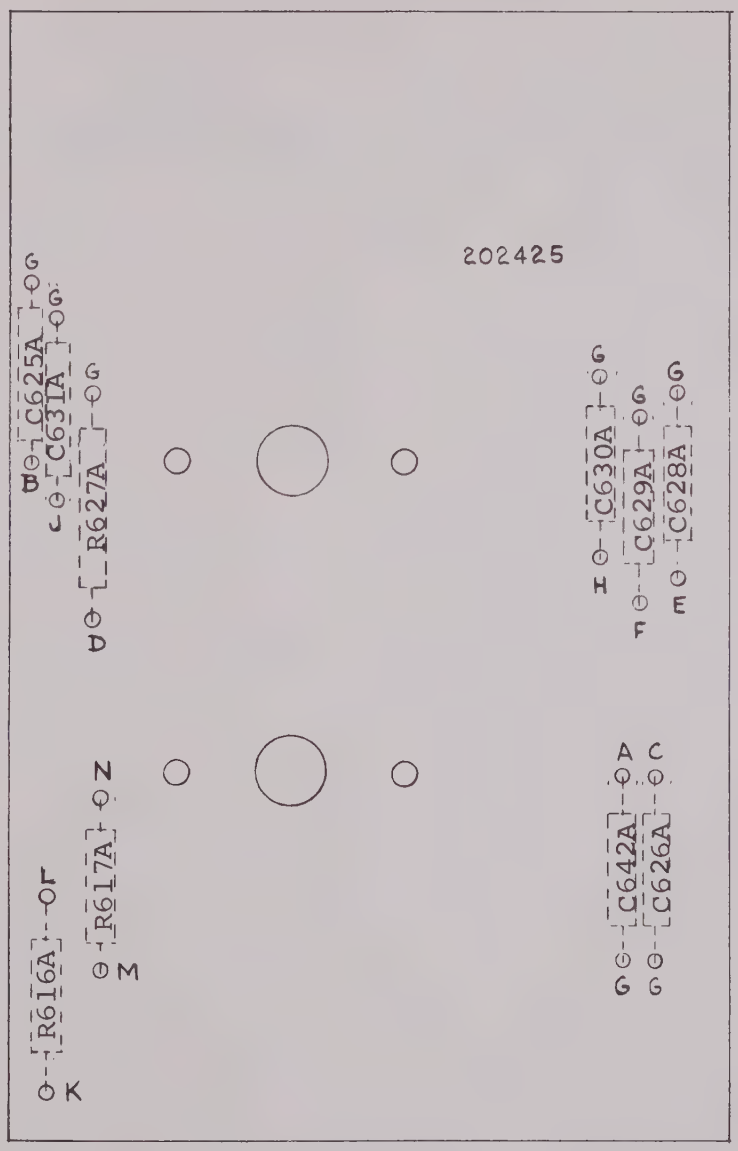


FRONT
FREQUENCY SWITCH
DECK #2

Figure 4.7

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

NOTE: Dash line components are select at test. See Figure 3.12 and Alignment Procedure, Paragraph XIII.



REAR
FREQUENCY SWITCH
DECK #2

Figure 4.8

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	DECK #2 SUB-ASSEMBLY	500608	
R616	Resistor, Fixed, D.C., 23.5K, 1/4W, ±1/2%	801707	
R617	Resistor, Fixed, D.C., 235Ω, 1/4W, ±1/2%	801697	
R618	Resistor, Fixed, D.C., 4.7K, 1/4W, ±1/2%	801706	
R619	Resistor, Fixed, D.C., 47Ω, 1/4W, ±1/2%	801694	
	DECK #3 SUB-ASSEMBLY Figures 4.9 & 4.10	500609	
C632	Capacitor, Fixed, .143ufd, 100V, ±1%	803619	Special
C633	Capacitor, Fixed, .0436ufd, 100V, ±1%	803599	Special
C634	Capacitor, Fixed, .0138ufd, 100V, ±1%	803600	Special
C635	Capacitor, Fixed, .00436ufd, 100V, ±1%	803601	Special
C636	Capacitor, Fixed, .204ufd, 100V, ±1%	803602	Special
C637	Capacitor, Fixed, .0642ufd, 100V, ±1%	803603	Special
C638	Capacitor, Fixed, .0204ufd, 100V, ±1%	803604	Special
C639	Capacitor, Fixed, .00642ufd, 100V, ±1%	803605	Special

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600

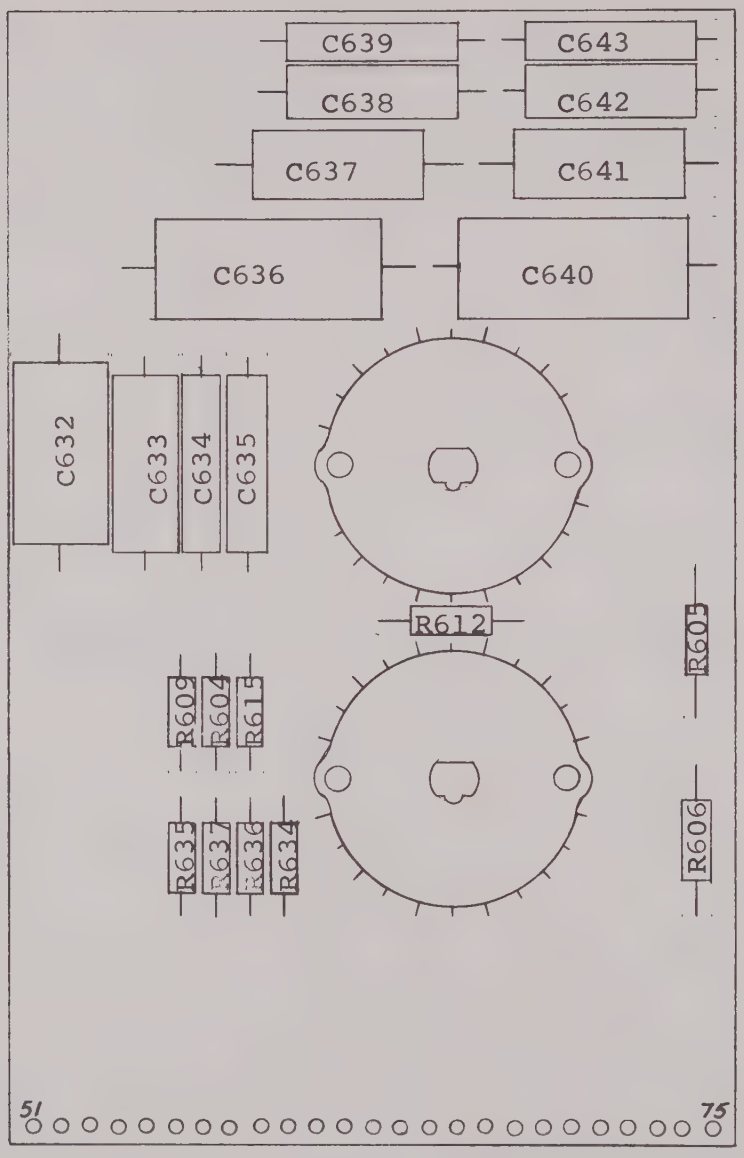
REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	DECK #3 SUB-ASSEMBLY Figures 4.9 & 4.10	500609	
C640	Capacitor, Fixed, .19ufd, 100V, ±2%	803592	Special
C641	Capacitor, Fixed, .06ufd, 100V, ±2%	803593	Special
C642	Capacitor, Fixed, .019ufd, 100V, ±2%	803606	Special
C643	Capacitor, Fixed, .006ufd, 100V, ±2%	803607	Special
C644	Capacitor, Fixed, 2.24ufd, 50V, ±1%	803576	Special
R604	Resistor, Fixed, DC, 66.5K, 1/4W, ±1%	801710	
R605	Resistor, Fixed, Comp., 24Ω, 1/2W, ±5%	800616	
R606	Resistor, Fixed, D.C., 583Ω, 1/4W, ±1/2%	802585	
R609	Resistor, Fixed, D.C., 665Ω, 1/4W, ±1%	801702	
R612	Resistor, Fixed, D.C., 438Ω, 1/4W, ±1/2%	801698	
R615	Resistor, Fixed, D.C., 43.8K, 1/4W, ±1/2%	801708	
R634	Resistor, Fixed, D.C., 3.95K, 1/4W, ±1%	800820	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

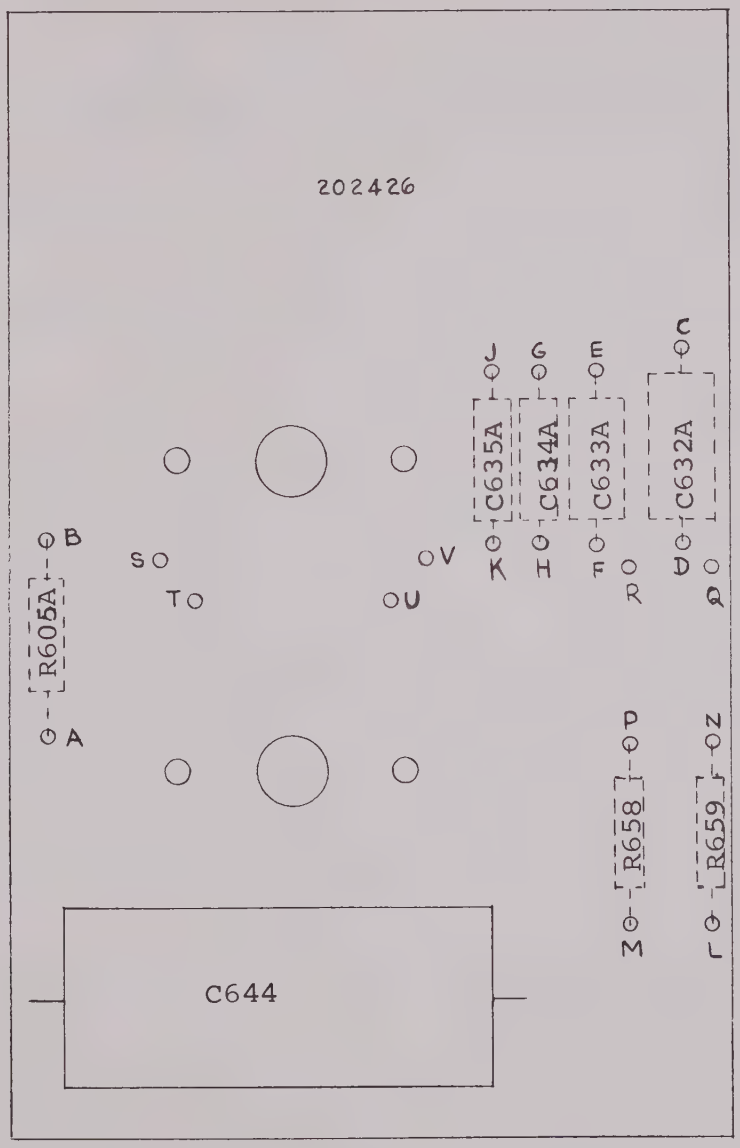


FRONT
FREQUENCY SWITCH
DECK #3

Figure 4.9

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Dash line components are select at test.
NOTE: See Figure 3.14 and Alignment Procedure, Paragraph XIII.



REAR
FREQUENCY SWITCH
DECK #3

Figure 4.10

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	DECK #3 SUB-ASSEMBLY	500609	
R635	Resistor, Fixed, D.C., 39.5Ω, 1/4W, ±1%	801693	
R636	Resistor, Fixed, D.C., 150K, 1/4W, ±1%	802451	
R637	Resistor, Fixed, D.C., 1.48K, 1/4W, ±1/2%	803612	
TB6	ASSEMBLY, TERMINAL BOARD Figure 4.11	500292	
C601, 602	Capacitor, Fixed, .0033ufd, 200V, ±10%	802221	
R601, 602	Resistor, Fixed, Comp., 680Ω, 1/2W, ±5%	800638	
R610, 624	Resistor, Fixed, Dep. Carb., 575Ω, 1/4W, ±1/4%	801700	
R620, 623	Resistor, Fixed, Dep. Carb., 2.25K, 1/4W, ±1/4%	801704	
R621, 622	Resistor, Fixed, Dep. Carb., 158Ω, 1/4W, ±1/4%	802763	
R625, 626	Resistor, Fixed, Dep., Carb., 28.5Ω, 1/4W, ±1/4%	801691	
R627	Resistor, Fixed, Dep. Carb., 53Ω, 1/4W, ±1%	801695	
R631	Resistor, Fixed, Dep. Carb., 166Ω, 1/4W, ±1%	802764	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

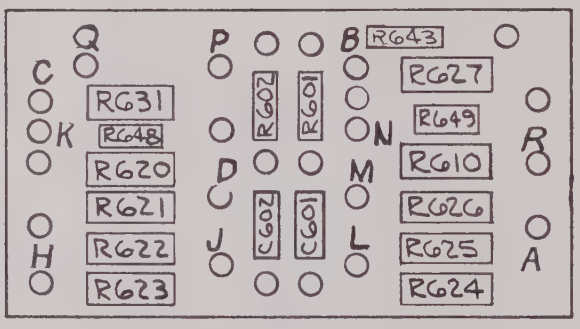
(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
TB6	ASSEMBLY, TERMINAL BOARD	500292	
R643	Resistor, Comp., 200Ω, 1/2W, ±5%	801672	
R648, 649	Resistor, Comp., 1/2W, (Select at Test)		
TB6A	TERMINAL BOARD Figure 4.12 This Terminal Board is added to all instruments after S/N #8251. It will contain all components selected at test which were formerly contained on the Frequency Switch Assembly. The function of these components is identical to their previous function. (See Schematics, Figures 3.12, 3.13, 3.14)		

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600



TERM. BOARD ASSY. (TB6)
500292

Figure 4.11

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

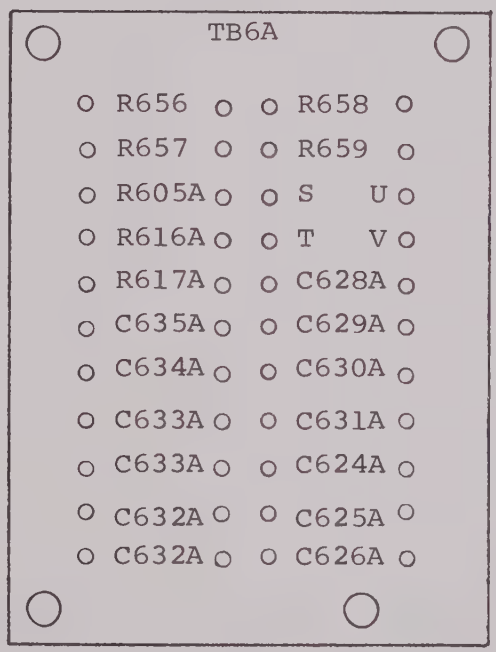


Figure 4.12

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, MONITOR VOLTMETER TERMINAL BOARD (Fig. 4.13)	500048	
C701	Capacitor, Fixed, 20ufd, 250V	801221	
C702	Capacitor, Fixed, .022ufd,200V	802219	
C703	Capacitor, Fixed, 100ufd, 6V	800600	
C704, 706	Capacitor, Fixed, .47ufd, 400V	800866	
C705	Capacitor, Fixed, 50ufd, 6V	800163	
C707	Capacitor, Fixed, .1ufd, 200V	802220	
CR701, 703	Diode, IN82A	800867	
CR702	Diode, IN461	800942	Clevite
R701, 710	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R702	Resistor, Fixed, Comp., 220Ω, 1/2W, ±10%	802301	
R703	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R704	Resistor, Fixed, Comp., 22K, 1/2W, ±10%	800155	
R705	Resistor, Fixed, Comp., 27K, 1/2W, ±10%	800088	
R706	Resistor, Fixed, Comp., 180K, 1/2W, ±5%	801260	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600

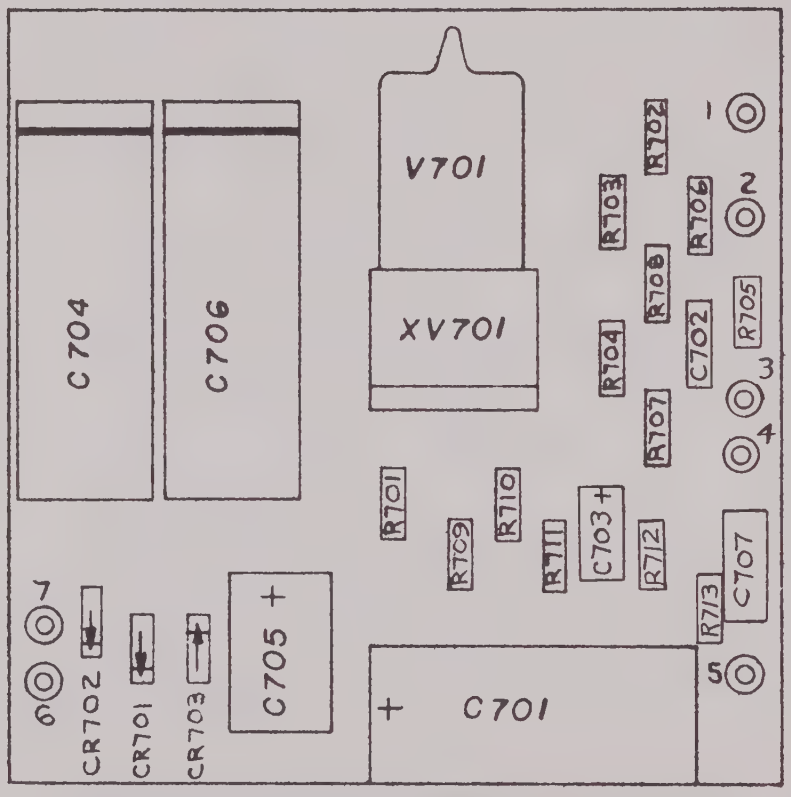
REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, MONITOR VOLTMETER TERMINAL BOARD (Fig. 4.13)	500048	
R707	Resistor, Fixed, Comp., 560Ω, 1/2W, ±5%	801258	
R708	Resistor, Fixed, Comp., 47Ω, 1/2W, ±5%	800855	
R709	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R711	Resistor, Fixed, Comp., 47K, 1/2W, ±10%	800087	
R712	Resistor, Fixed, Comp., 680Ω, 1/2W, ±5%	800638	
R713	Resistor, Fixed, Comp, 2Meg., 1/2W, ±5%	802173	
V701	Tube, Electron, 6U8A	800028	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600



MONITOR VOLTMETER TERMINAL BOARD ASSY.
500048

Figure 4.13

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.14	500050	
C801,805, 806, 822	Capacitor, Fixed, .1ufd, 200V, ±10%	802220	
C802	Capacitor, Fixed, .0022ufd, 400V, ±10%	802240	
C803	Capacitor, Fixed, .01ufd, 200V, ±10%	801879	
C804	Capacitor, Fixed, 30ufd, 250V	802774	
C807	Capacitor, Variable, 5-25 uuf	801483	
C808	Capacitor, Fixed, .0047ufd, 200V, ±10%	802239	
C809, 812	Capacitor, Fixed, .0018ufd, 400V, ±10%	802236	
C810, 811	Capacitor, Fixed, .0047ufd, 400V, ±5%	802281	
C813, 815	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C814	Capacitor, Fixed, 100uufd, 500V, ±5%	801264	
C816, 817	Capacitor, Fixed, 0.1uf, 200V, ±10%	802220	
C818, 819	Capacitor, Fixed, 4ufd, 200V, ±5%	802245	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.14	500050	
C820, 821	Capacitor, Fixed, .022uf, 400V	802235	
C823	Capacitor, Fixed, .22uf, 100V	802863	
C824	Capacitor, Fixed, 27uuf, 500V	801925	
R801	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R802,805,811, 814,822,823, 832,837	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R803,810,824	Resistor, Fixed, Comp., 100K 1/2W, ±10%	800086	
R804	Resistor, Fixed, Comp., 4.3K 1/2W, ±5%	800621	
R806	Resistor, Fixed, Comp., 5.6K, 1/2W, ±5%	800641	
R807	Resistor, Fixed, Dep. Carb., 10.4K, 1/4W, ±1%	802840	
R808	Resistor, Fixed, Comp., 1K, 1/2W, ±5%	800414	
R809	Resistor, Fixed, Dep. Carb., 9K, 1/4W, ±1%	802717	
R812	Resistor, Fixed, Comp., 240K, 1/2W, ±5%	801282	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.14	500050	
R815,825	Resistor, Fixed, Comp., 68K, 1/2W, ±5%	800528	
R816,821	Resistor, Fixed, Comp., 6.2K, 1/2W, ±5%	800614	
R826,829,830, 831	Resistor, Fixed, Comp., 110K, 1/2W, ±5%	800682	
R817,820	Resistor, Fixed, Comp., 8.2K, 1/2W, ±5%	800626	
R818,819	Resistor, Fixed, Comp., 22M, 1/2W, ±10%	801754	
R827, 828	Resistor, Fixed, Comp., 470Ω, 1/2W, ±10%	800084	
R833,836	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	
R834,835	Resistor, Fixed, Comp., 68Ω, 1/2W, ±5%	801139	
R838,847,850	Resistor, Fixed, Dep. Carb., 40Ω, 1/4W, ±1%	802862	
R839,842	Resistor, Fixed, Comp., 24K, 2W, ±5%	802246	
R840,841	Resistor, Fixed, Dep. Carb., 5.6K, 1/4W, ±1%	802247	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

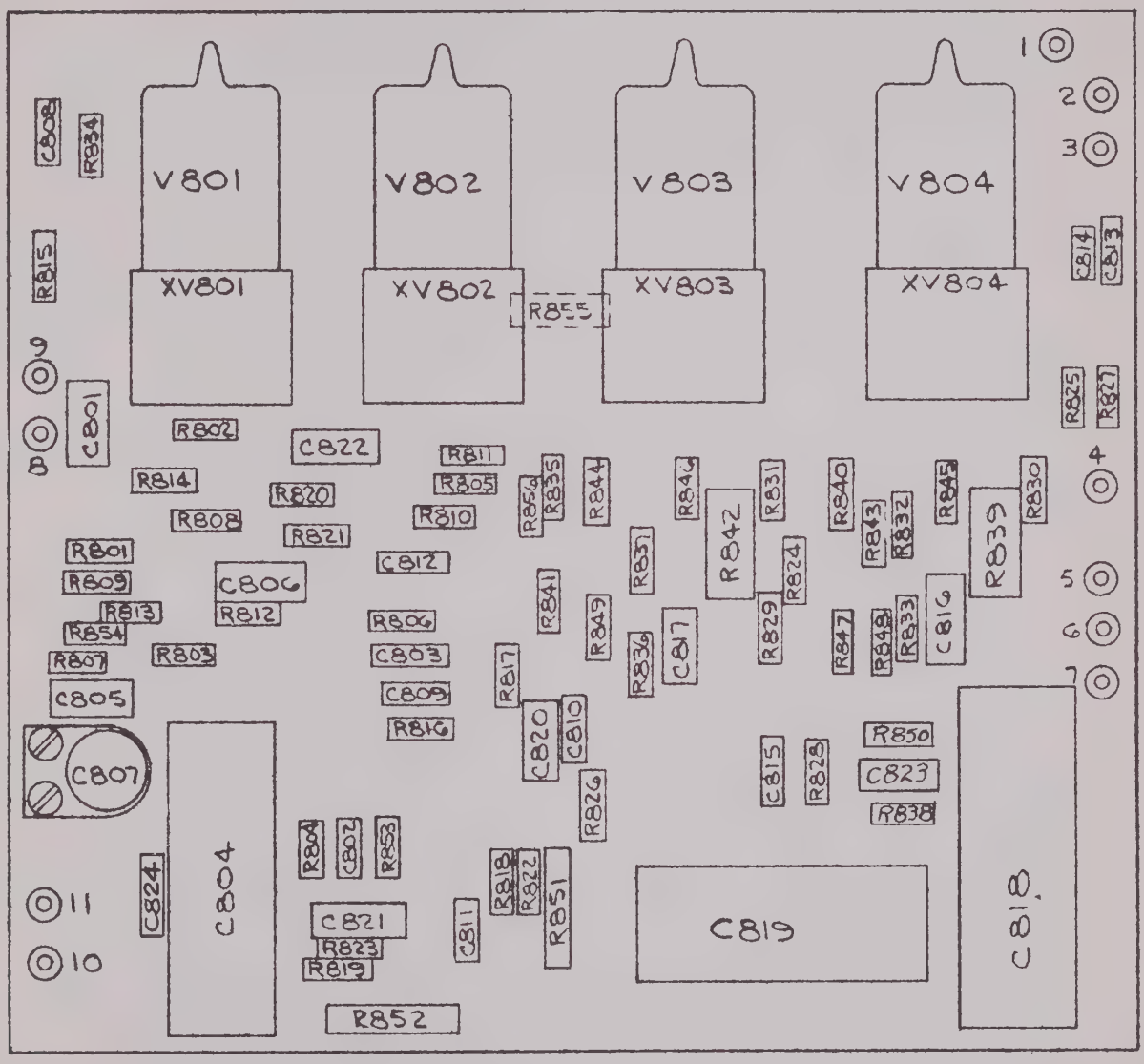
REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.14	500050	
R843,844	Resistor, Fixed, Dep. Carb., 1.5K, 1/4W, ±1%	802248	
R845,846	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	
R848,849	Resistor, Fixed, Dep. Carb., 910Ω, 1/4W, ±1%	802249	
R851,852	Resistor, Fixed, Dep. Carb., 10M, 1W, ±1%	802253	
R853	Resistor, Fixed, Comp., 22K, 1/2W, ±10%	800155	
R854	Resistor, Fixed, Comp., 200K, 1/2W, ±5%	801873	
R855	Resistor, Fixed, W.W. 0.56Ω, 2W, ±10%	802399	
R856,813	Resistor, Select at Test, Nominally 2.4 Meg.		
V801,802	Tube, Electron, 6U8A	800028	
V803,V804	Tube, Electron, 6AN8	801521	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600



REFERENCE DRIVE AMPLIFIER ASSEMBLY

500050

Figure 4.14

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.15	500083	
*C901	Capacitor, Fixed, 20ufd, 350V	800847	* Used as input cap. with silicon rectifier.
*C902	Capacitor, Fixed, 30ufd, 250V	801528	
*C903,904 909	Capacitor, Fixed, 20ufd, 250V	801221	
C905	Capacitor, Fixed, .0022 ufd, 400V, ±10%	802240	
C906	Capacitor, Fixed, .01ufd, 200V, ±10%	801879	
C907	Capacitor, Fixed, 24uufd, 500V, ±5%	802216	
C908	Capacitor, Fixed, .33ufd, 200V, ±10%	801527	
C910	Capacitor, Fixed, 20ufd, 450V	801222	
C911	Capacitor, Fixed, 100ufd, 500V, ±10%	801264	
C913	Capacitor, Fixed, .001ufd, 200V, ±10%	802218	
C914	Capacitor, Fixed, 150uufd, 500V, ±5%	801365	
C915	Capacitor, Fixed, 4ufd, 350V	800888	
C916	Capacitor, Fixed, 10ufd, 50V	802209	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.15	500083	
CR901,902	Diode, SR200B	803735	Sylvania
CR903,904	Diode, IN2071	800986	
CR905,906	Diode, IN1692	800987	G.E.
DS902	Lamp, Neon, NE76	801523	
Q901	Transistor, TR650	801522	
Q902	Transistor, 2N398	801520	
Q903	Transistor, 2N1539	802441	
Q904,905	Transistor, 2N1381	800872	
Q906	Transistor, 2N697	802107	AMPEREX
R901,902,910, 916	Resistor, Fixed, Comp., 22Ω, 1/2W, ±10%	800988	
R903,R904	Resistor, Fixed, WW, 2.5K, 3W, ±5%	802374	
R905	Resistor, Fixed, Metal Film, 160K, 1/2W, ±1%	802347	
R906	Resistor, Fixed, Metal Film, 82K, 1/2W, ±1%	802348	
R907,922,929	Resistor, Fixed, Comp., 220K, 1/2W, ±10%	800058	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4,15	500083	
R908**	Resistor, Fixed, Comp., 27K, 1/2W, ±10%	800088	
R909	Resistor, Fixed, Comp., 430Ω 1/2W, ±5%	800640	
R911	Resistor, Fixed, Comp., 160K, 1/2W, ±5%	800859	
R912**	Resistor, Fixed, Comp., 33K, 1/2W, ±10%	800839	
R913	Resistor, Fixed, Comp., 100K, 1/2W, ±10%	800086	
R914	Resistor, Fixed, Comp., 470K, 1/2W, ±10%	800060	
R915	Resistor, Fixed, Comp., 2.7Ω, 1W, ±10%	801738	
R917	Resistor, Fixed, WW, 25Ω, 3W, ±5%	800075	
R918	Resistor, Fixed, WW, 5K, 7W, ±10%	802463	
R919	Resistor, Fixed, Metal Film, 35K, 1/4W, ±1%	802543	
R920	Resistor, Fixed, Comp., 36K, 1/2W, ±5%	801016	
** Nominal value - trimmed at test.			

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.15	500083	
R921	Resistor, Fixed, Comp., 47Ω,	800991	
R923	Resistor, Fixed, Metal Film, 218K, 1/2W, ±1%	802210	
R924	Resistor, Fixed, Metal Film, 14K, 1/2W, ±1%	802439	
R925	Resistor, Fixed, Comp., 4.7K, 1/2W, ±10%	800078	
R926	Resistor, Fixed, Comp., 68K, 1/2W, ±5%	800528	
R927	Resistor, Fixed, Comp., 150Ω, 1/2W, ±5%	801140	
R928	Resistor, Fixed, Comp., 12K, 1/2W, ±5%	800644	
R930**	Resistor, Fixed, Comp., 39K, 1/2W, ±10%	801069	
R932	Resistor, Fixed, Comp., 30K, 1/2W, ±5%	800622	
R933	Resistor, Fixed, Comp., 1.5M, 1/2W, ±5%	802214	
R934	Resistor, Fixed, Comp., 150K, 1/2W, ±5%	800856	

** Nominal value - trimmed at test.

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

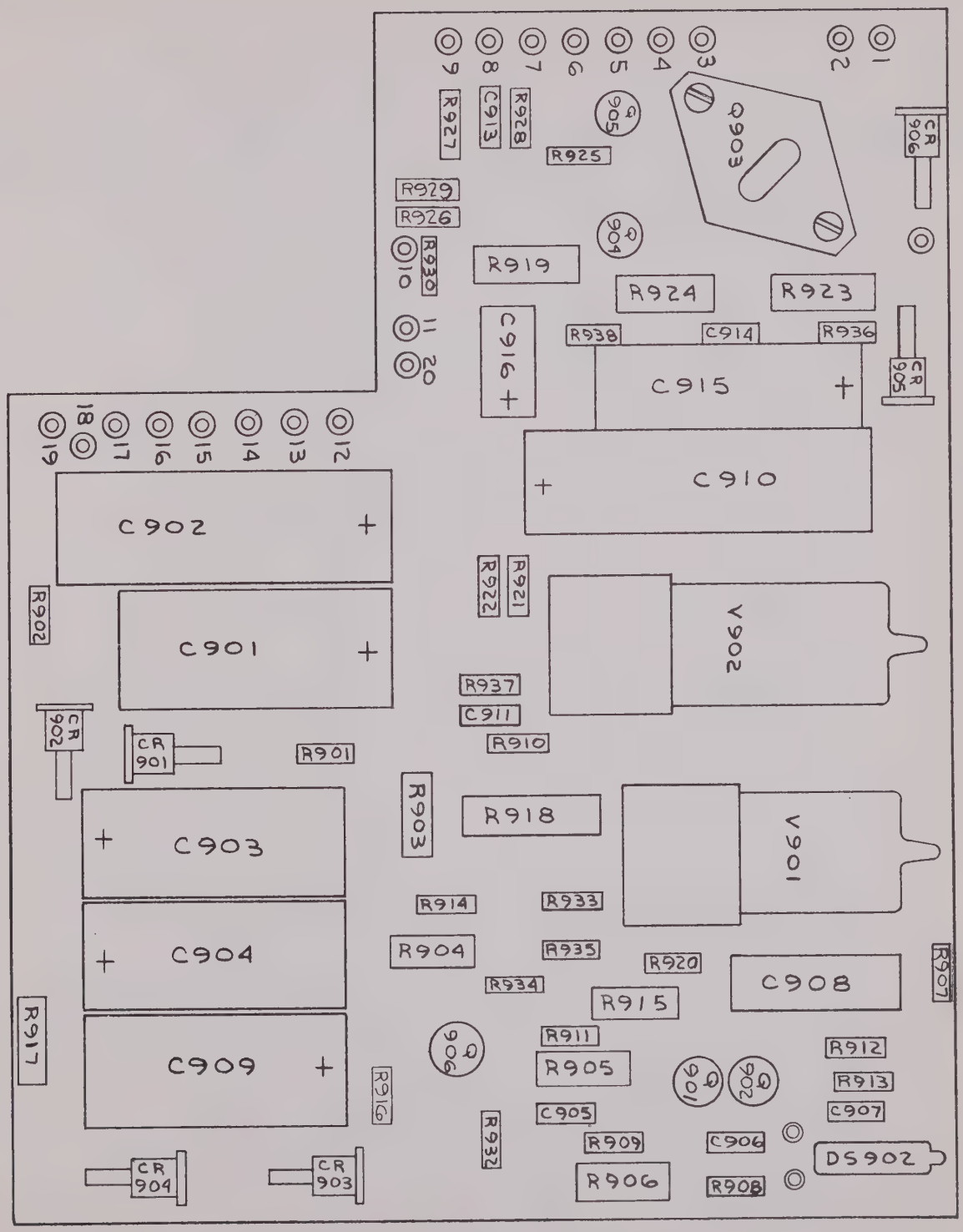
CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.15	500083	
R935	Resistor, Fixed, Comp., 270K, 1/2W, ±5%	802213	
R936	Resistor, Fixed, Comp., 110Ω, 1/2W, ±5%	801145	
R937**	Resistor, Fixed, Comp., 240K, 1/2W, ±5%	801282	
R938**	Resistor, Fixed, Comp., 1.8K, 1/2W, ±5%	800858	
V901	Tube, Electron, 6AN8	801521	
V902	Tube, Electron, 12B4A	800973	

** Nominal value - trimmed at test.

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600



POWER SUPPLY TERMINAL BOARD ASSY.
500083

Figure 4.15
4.49

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *overbrook 1-8600*

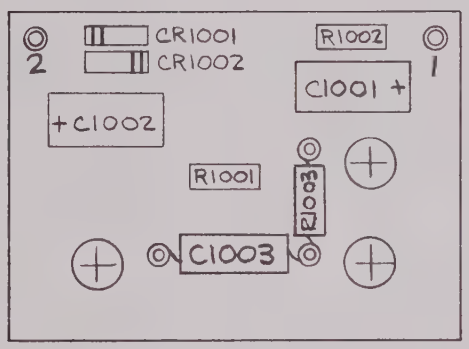
REPLACEMENT PARTS LIST

DESIGNATION	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Meter Board Figure 4.16	500181	
C1001,C1002	Capacitor, Fixed, 50uf, 6V	800163	
C1003	Capacitor, Fixed, .047uf, 400 400V	802395	
CR1001,1002	Diode, 1N461	800942	Clevite
R1001	Resistor, Fixed, Comp., 10Ω, 1/2W, ±10%	801518	
R1002	Resistor, Fixed, Comp., 3K, 1/2W, ±5%	800615	
R1003	Resistor, Fixed, Comp., 22 Meg, 1/2W, ±10%	802395	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600



METERBOARD ASSEMBLY

500181

Figure 4.16

REPLACEMENT PARTS LIST

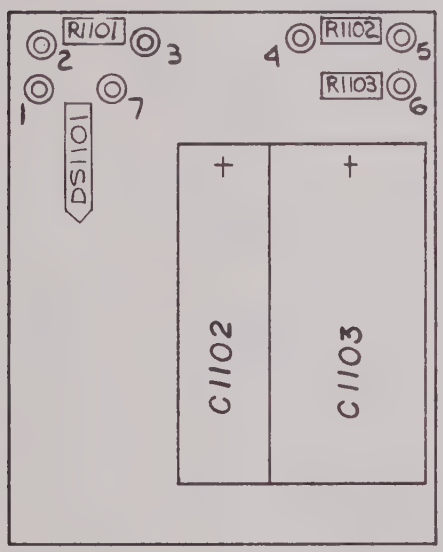
(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Decoupling Board Figure 4.17	500177	
C1102	Capacitor, Fixed, 4ufd, 350V	800888	
C1103	Capacitor, Fixed, 50ufd, 250V	801737	
DS1101	Lamp, Neon, NE76	801523	
R1101	Resistor, Fixed, Comp., 220K, 1/2W, ±5%	800977	
R1102	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	
R1103	Resistor, Fixed, Comp., 20K, 1/2W, ±5%	800521	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600



SIG. DE-COUPLING BOARD ASSY.
500177

Figure 4.17

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

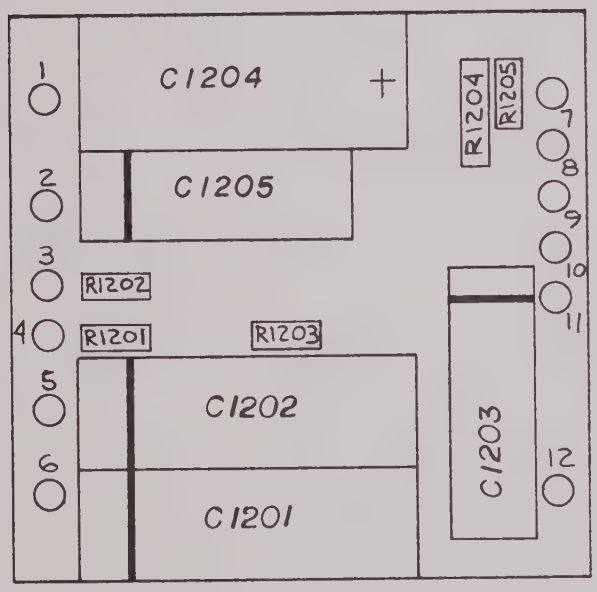
REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Filter and Overload Figure 4.18	500276	
C1201,1202	Capacitor, Fixed, .22ufd, 400V, ±20%	800021	
C1203,1205	Capacitor, Fixed, .1ufd, 400V, ±20%	800020	
C1204	Capacitor, Fixed, 20ufd, 350V	800847	
R1201	Resistor, Fixed, Comp., 270K, 1/2W, ±10%	800059	
R1202	Resistor, Fixed, Comp., 130K, 1/2W, ±5%	800806	
R1203	Resistor, Fixed, Comp., 2.2K, 1/2W, ±5%	800079	
R1204	Resistor, Fixed, Dep. Carb., 11K, 1/2W, ±1%	801662	
R1205	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600



SIGNAL FILTER & OVERLOAD ASSY.
500276

Figure 4.18

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Range Switch	782401	
	Sub-Assembly Deck #1	500615	
C1301	Capacitor, Variable, 3-12uufd	801512	
C1303	Capacitor, Fixed, .1ufd, 600V	802789	
C1304	Capacitor, Fixed, .027ufd, 100V, ±5%, Polystyrene	802571	
C1305	Capacitor, Fixed, 3.9uufd, 500V, ±5%	802163	
C1317	Capacitor, Fixed, 22uufd, ±5%	802572	
C1318	Capacitor, Fixed, .22ufd, 200V	802790	
R1301	Resistor, Fixed, Metal Film, 10M, 1/2W, ±1/2%	802516	
R1302	Resistor, Fixed, Metal Film, 10K, 1/2W, ±1/4%	802517	
R1303	Resistor, Fixed, Comp., 12K, 1/2W, ±5%	800644	
R1304	Resistor, Fixed, Comp., 120Ω, 1/2W, ±5%	800407	
R1305,1319	Resistor, Fixed, Comp., 20M, 1/2W, ±5%	801482	
R1318	Resistor, Fixed, W.W., .75Ω, 2W, ±5%	802583	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Range Switch	782401	
	Sub-Assembly Deck #2	500616	
C1302	Capacitor, Variable, 6-25uufd	802793	
C1306	Capacitor, Fixed, 43uufd, 500V ±2%	802446	
C1307	Capacitor, Fixed, 150uufd, 500V, ±2%	802447	
C1308	Capacitor, Fixed, 220uufd, 500V, ±5%	802448	
C1309	Capacitor, Fixed, 250uufd, 500V, ±5%	802449	
C1310	Capacitor, Fixed, 300uufd, 300V, ±5%	802450	
C1311, 1312,1313, 1314,1315,1316	Capacitor, Fixed, .1ufd, 200V, ±10%	802220	
CR1301,1302	Diode, IN658	801661	Clevite
R1306	Resistor, Fixed, Metal Film, 6.84K, 1/8W, ±1/4%	801474	
R1307	Resistor, Fixed, Metal Film, 2.16K, 1/8W, ±1/4%	801475	
R1308	Resistor, Fixed, Metal Film, 684Ω, 1/8W, ±1/4%	801476	

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REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Range Switch	782401	
	Sub-Assembly Deck #2	500616	
R1309	Resistor, Fixed, Metal Film, 216Ω, 1/8W, ±1/4%	801477	
R1310	Resistor, Fixed, Metal Film, 68.4Ω, 1/8W, ±1/4%	801478	
R1311	Resistor, Fixed, Metal Film, 31.6Ω, 1/8W, ±1/4%	801479	
R1312,1313, 1314,1315, 1316,1317	Resistor, Fixed, Comp., 20M, 1/2W, ±5%	801482	

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REPLACEMENT PARTS LIST

LOOSE COMPONENTS

CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
C313	Capacitor, Fixed, 3.9MMF, 500V, ±5%	802163	
C314	Capacitor, Fixed, 220MMF, 500, ±5%	802448	
C315	Capacitor, Fixed, 130MMF, 500V, ±5%	802175	
C316	Capacitor, Fixed, 200MMF, 500V, ±5%	802168	
C317	Capacitor, Fixed, 160MMF, 500V, ±5%	802560	
C607	Capacitor, Fixed, 18MMF, 500V, ±5%	802423	
C912	Capacitor, Fixed, 1000MF, 25V	800982	
R242	Potentiometer, 250Ω, 1/2W	801471	
R320	Resistor, Fixed, Comp., 12K, 1/2W,±5%	800644	
R321	Potentiometer, Ref. Level	B-202788	
R322	Resistor, Fixed, Comp., 56Ω, 1/2W, ±5%	801653	
R505	Potentiometer, 1.5K, 2W, (Zero)	803621	
R603	Resistor, Fixed, Comp. (Select at Test)		
R628, 630	Resistor, Fixed, D.C., 90.6K, 1/2W, ±1/4%	802786	

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REPLACEMENT PARTS LIST

LOOSE COMPONENTS

CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
R632	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R633	Potentiometer, 100Ω, 2W, (Equal)	803622	
R638, 641	Resistor, Fixed, D.C., 906Ω, 1/2W, ±1/4%	802785	
R639	Resistor, Fixed, Comp., 1K, 1/2W, ±10%	800166	
R644	Potentiometer, (Phase)	C-802811-1	
R939	Resistor, Fixed, Comp., 5.1Ω, 1W, ±10%	803869	
R1003	Potentiometer, 50K, 2W	800056	
XF1	Fuseholder	800137	
F1	Fuse, 2Amp., 3AG	800935	
	Link, Shorting	800339	
	Binding Post (Red)	800119	
	Binding Post (Black)	800120	
	Binding Post (Ground)	800546	
M701	Meter, Ref. Level	B-800565	
B1	Motor , Fan	803665	
	Knob, Small Round	B-201720	
	Knob, Small Round(with white indicator line)	B-201720-1	

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REPLACEMENT PARTS LIST

LOOSE COMPONENTS

CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
	Knob, Medium Pointer	B-201719-1	
	Knob, Large Round	B-201724	
	Knob (Freq. Switch)	A-202796	
	Cord, Std. Thin Nylon	900642	Gen. Cement #75
	Spring, Dial Drive	803614	Walsco #7407-F
DS1201	Lamp, Overload	A-202778	
XDS1201	Connector, Cartridge	802951	Dialco #7538-XP12
	Clip, Speed	802952	Dialco #7538-XP51
DS3,DS4	Lamp, Midget Screw Base #1768	802767	
DS5,DS6	Lamp, Meter #51	803611	
XDS3,XDS4	Lampholder, Midget Screw Base	802768	Dialco #16-08
	Meter & Filter Door Assembly	500624	
R105	Potentiometer, 5K, 1/2W	801472	
R108	Resistor, Fixed, D.C., 5K, 1/2W, ±1%	801166	
R318	Resistor, Fixed, D.C., 10K, 1/2W, ±1%	801481	
M1001	Meter	202556	

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REPLACEMENT PARTS LIST

LOOSE COMPONENTS

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Phase Dial Assembly	500619	
T601	Driver Transformer (LF)	200612	
T602	Driver Transformer (HF)	200611	
T901	Power Transformer	200688	
R242	Potentiometer, 250Ω, 1/2W	801471	
R321	Potentiometer. Ref. Level	202788	
R505	Potentiometer, 1.5K, 2W (Zero)	803621	
R633	Potentiometer, 100Ω (Equal)	803622	
R644	Potentiometer (Phase)	802811-1	
R320	Resistor, Fixed, Comp., 12K, 1/2W, ±5%	800644	
R322	Resistor, Fixed, Comp., 56Ω, 1/2W, ±5%	801653	
R603	Resistor, Fixed, Comp., Select at Test		
R628,R630	Resistor, Fixed, DC, 90.6K, 1/2W, ±1/4%	802786	
R638,R641	Resistor, Fixed, DC, 906Ω, 1/2W, ±1/4%	802785	
R632	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R639	Resistor, Fixed, Comp., 1K, 1/2W, ±10%	800166	

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REPLACEMENT PARTS LIST

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
R939	Resistor, Fixed, Comp., 4.7Ω, 1W	803869	
C313	Capacitor, Fixed, 3.9uuf, 500V, ±5%	802163	
C314	Capacitor, Fixed, 220uuf, 500V, ±5%	802448	
C315	Capacitor, Fixed, 130uuf, 500V, ±5%	802175	
C316	Capacitor, Fixed, 200uuf, 500V, ±5%	802168	
C317	Capacitor, Fixed, 160uuf, 500V, ±5%	802560	
C607	Capacitor, Fixed, 18uuf, 500V, ±5%	802423	
C912	Capacitor, Fixed, 1000uf, 25V	800982	
	Function Switch Assembly	500625	
R629	Resistor, Fixed, DC, 93.7K, 1/4W, ±1%	801622	
R640	Resistor, Fixed, DC, 937Ω, 1/4W, ±1%	801621	
	Filter In-Out Switch Ass'y	500626	
	Switch, Level (HI-LO)	202398	

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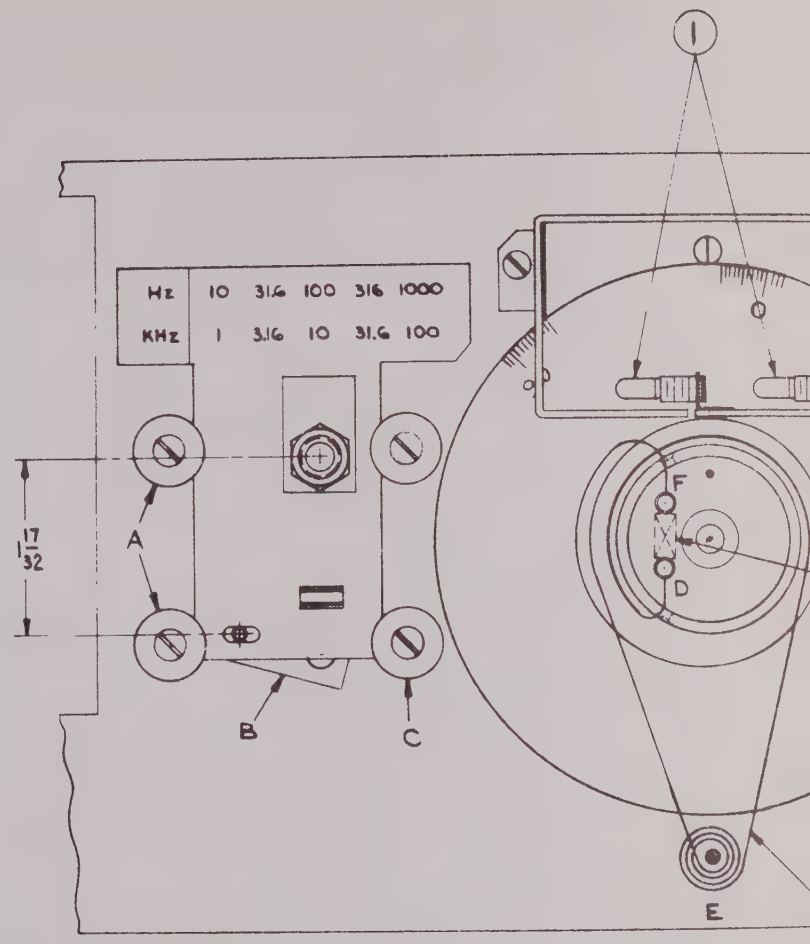

SHOWN WITH FRONT PANEL REMOVED

Item 1.	NAI# 802767	Lamp
Item 2.	NAI# 803614	Spring, Dial Drive
Item 3.	NAI# 900642	Cord, Dial Drive

FREQUENCY SWITCH SLIDE ADJUSTMENT

(FRONT PANEL REMOVED)

1. Loosen 2 screws supporting adjustable guides "A".
2. Move guides to right against slide and tighten screws.
3. Adjustment is correct when switch may be operated smoothly with a minimum of side to side play of slide.
4. With lower switch (2 position) in extreme clockwise position, adjust block "B" to dimension shown and tighten set screw. Remove single guide "C" and tighten second set screw in block. Replace guide "C".

DRIVE CORD REPLACEMENT, PHASE DIAL

(FRONT PANEL REMOVED)

1. Rotate dial to extreme clockwise position.
2. Starting at spring loop "D", tie one end of cord.
3. Pass other end of cord thru c'sunk hole and wind clockwise approx. 3/4 turn.
4. Pass cord under lower shaft "E" and wind clockwise, 3½ turns.
5. Pass cord over dial hub and wind clockwise approx. 1-1/4 turns; thru second c'sunk hole and then thru spring loop "F". Tie cord while elongating and maintaining tension on spring.
6. Cut off excess cord at knots.
7. When necessary to increase friction, use dial cord dressing N.A.I. #900650.

LAMP REPLACEMENT, PHASE DIAL

(WITH OR WITHOUT FRONT PANEL REMOVED)

Without front panel removed:

1. Remove 2 screws, "G" from rear of sub-panel.
2. Move lamp bracket "H" upward until lamps are accessible for removal.
3. To re-assemble, reverse procedure above.

FIGURE 4.19

SECTION V

TEST AND ALIGNMENT PROCEDURE

It is the purpose of this procedure to assist a qualified technician in the recalibration of the Model 301A Phase Angle Voltmeter. Under normal circumstances, this instrument, due to the use of solid-state circuitry, should require a minimum of service and recalibration.

The Test Procedure portion of Section V may be used for incoming acceptance test or for periodic calibration checks. It is recommended that the initial periodic check be made every 3 months and future checks be expanded to 5 months or yearly checks.

The Alignment Procedure portion of Section V may be used for recalibration in the event there is a failure which requires the replacement of any module or component in the instrument.

TEST EQUIPMENT REQUIRED

1.	AC VTVM	Ballantine 300H or equivalent
2.	Audio Signal Generator	
3.	Phase Standard	Capable of generating: a. $90^{o} \pm .05^{o}$ from 10Hz to 100KHz. b. $45^{o} \pm .05^{o}$ at 1KHz.
4.	Attenuator	Kay Electric 31-0 or equivalent
5.	Power Amplifier	Khronhite DC 10A, or equal.
6.	Multitester	Hewlett-Packard 412A Meter or equal.

I. GROUND CHECK

Check for stray ground path. Should read OPEN (no reading on Multitester X100,000 Range) from signal ground (black terminal post) to chassis (metal terminal post).

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II. NOISE CHECK (Filters must be plugged in before proceeding).

With signal input shorted in the VTVM position, noise as read on the meter shall be as follows:

Filter OUT 10uv max. Noise_____

Filter In 20uv max. Noise_____

III. NULL CHECK

With input shorted (reference connected) Phase Sensitive Mode output meter should read:

Up to 31.6KHz, 2uv Max. Null_____

3.16KHz to 100KHz, 10uv Max. Null_____

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IV. VOLTAGE ACCURACY

Maximum error ± 2% - (Operate at 90% of F.S.)

Range	50Hz	1KHz	5KHz
.001			
.003			
.01			
.03			
.1			
.3			
1.0			
3.0			
10.0			
30.0			
100.0			
300.0			

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V.

A. Phase Accuracy Check (Read with calibrated Phase Dial, @ 10X Overload)

Maximum Errors:

Bands 2-7 (31.6Hz to 31.6KHz) ± .25°

Band 8 (31.6KHz to 100KHz) Gradual degradations as frequency is increased to ±1° @ 100KHz.

Band 1 (10Hz to 31.6Hz) Gradual degradations as frequency is decreased to ± .6° @ 10Hz.

Signal Input 10mv Reference Input 100V

B. Low Reference Level Checks

Set Reference Input to .15V at 1KHz and check at 1KHz Low (last column on the following Data Chart).

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PHASE ACCURACY
AND
LOW REFERENCE LEVEL CHECKS

ANGLE 0-90 90-90	100Hz	FREQUENCY 1KHz Low	1KHz Hi	10KHz	.15V Ref 1KHz Low
10					
20					
30					
40					
45					
50					
60					
70					
80					
0-0 90-90					
135					
180					
225					
270					
315					
360					

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VI. OVERLOAD CHECK

Increase input on any range until overload light ignites. Should be 11:1 Nom.

Overload Ignites_____

ALIGNMENT PROCEDURE

I. INITIAL GROUND CHECK

Check for stray ground path. Should read OPEN (no reading on Multitester X100,000 Range) from signal ground (black terminal post) to chassis (metal terminal post).

II. INITIAL POWER SUPPLY VOLTAGE CHECK

A. Short reference and signal input terminals. Short signal ground post and chassis (metal post).

B. Third prong on power plug should be connected to a house ground.

C. Apply power to Phase Angle Voltmeter. Observe that filaments and pilot lights are on. Make sure that neon light on power supply ignites within a minute.

D. All instruments have been carefully factory inspected and calibrated. The instrument should have an output between the limits listed below in DC VOLTS and an AC ripple level

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below that listed.

Pin	DC Volts	AC VTVM
*10	-79 to -81	Approx. 600uv
11	+260 to +270	Approx. 1mv
12	+175 to +200	High 10-20 volts
15	+260 to +270	Approx. 90mv
7	+12 to +12.6	Approx. 3mv
8	Ground (Tied to Signal Ground in Signal Amplifier)	
16	-120 to -140 volts	200mv approx.

Due to tube ageing, etc., the instrument may not remain within the above limits, and adjustment should be made. The appropriate controls for each output are listed below. The DC amplitude adjust noted is to be used to raise the DC voltage level. The AC ripple adjust noted is to be used to raise the DC voltage level. The AC ripple adjust noted is to be used to lower the particular ripple level.

Pin	DC Amplitude Adjust	Ripple Adjust
10	R908 (27K nom.)	R912 (33K nom.)
11	R938 (1.8K nom.)	R937 (240K nom.)
7	R930 (39K nom.)	No adj.

*In the event that the -80 volts is adjusted, the +260 volt level must be rechecked as there is a reaction due to the inter-action of the -80 volts and +260 volts.

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III. VOLTAGE RANGE ADJUSTMENT (LOW RANGE)

The purpose of this adjustment is to calibrate the full scale voltage sensitivity of the Signal Channel. This calibration will adjust the sensitivity of the 1mv to 300mv set of ranges.

A. Connect Signal Generator to an AC VTVM and input of the attenuator.

B. Connect output of attenuator to input of VM-301A.

C. Switch FUNCTION Switch to "VM" (VM-301A). Switch FILTER Switch to "OUT" (VM-301A).

D. Adjust Signal Generator to 1KHz and 1 volt output.

E. Set attenuator to 100 millivolts output.

F. Set RANGE Switch to 100 millivolts range and adjust calibrate potentiometer R242 on back panel for exactly 100 millivolts on voltmeter (VM-301A).

G. In steps corresponding to the RANGE Switch steps, check all ranges from 1mv to .3 volts.

H. Repeat Steps A through G at 10Hz, 100Hz, 10KHz, 50KHz, and 100KHz.

NOTE: All readings should be within ± 2% from 10Hz to 100KHz.

IV. REFERENCE PRE-AMP ADJUSTMENT

(This should be done any time Tube V-301 is changed.) This will adjust the DC voltage across the Reference Adjust Potentiometer to zero and ensure smooth operation of this control.

A. Adjust DC voltage on Pin 16 of D-500086 (Reference

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Pre-Amp) to equal zero with R309 (located on the Reference Pre-Amp Board).

V. REFERENCE CHANNEL SENSITIVITY

This procedure is to ensure proper reference sensitivity.

A. Adjust Signal Generator to 1000Hz and approximately .3 volts output. Apply to reference input terminals.

B. Short signal input terminals (VM-301A).

C. Switch FREQUENCY Switch to "Hz" and "316 to 1000."
Switch FUNCTION Switch to "0" degrees.
Switch FILTER Switch to "OUT."
Switch REFERENCE LEVEL Switch to "LO."

D. Adjust Reference Level Potentiometer to give approximately half scale reading on Reference Level Meter.

E. Decrease the reference signal input slowly, readjusting Reference Level Control to keep pointer of Reference Level Meter on scale. The pointer should be on scale until the reference input is reduced to approximately .14 volts input.

VI. COMMON MODE ADJUSTMENTS

This procedure will balance the push-pull output voltage of the Reference Drive Amplifier so that the voltmeter will read a null with a normal reference input and zero signal input. This balance will be done in the mid-band of frequencies and at 100KHz.

A. Repeat Steps A to D of Paragraph V.

B. Voltmeter should read ±2uv independent of RANGE Switch or Phase Sensitive position of FUNCTION Switch. If this

reading is exceeded, adjust R847 or R850 as required for a null.

C. Adjust Signal Generator to 100KHz and repeat A through D of Paragraph V. Note that FREQUENCY Switch should be on "KHz" and "31.6-100".

D. Adjust C807 on Reference Drive Amplifier for a null.

E. Set FREQUENCY Switch to "Hz" and "10-31.6". Adjust Signal Generator to 10Hz. Repeat Steps A through D of Paragraph V.

F. Voltmeter should read ± 2uv independent of RANGE Switch or Phase Sensitive position of Function Switch. If this reading is exceeded, adjust R813 or R856 as required for a null.

VII. ZERO-EQUAL CONTROL OPERATIONS

Before continuing further with the tests, review the following points:

A. Whenever phase sensitive measurements are being made, it is necessary to zero and equal the Model VM-301A each time the frequency is changed. This is necessary in the following test and should be done when the frequency is changed. This will be referred to as "EQUAL" or "ZERO".

B. EQUAL: This is done by adjusting the Reference Signal Level to obtain an on-scale reading on the Reference Level Meter. Depress the EQUAL Switch and adjust the EQUAL Control so that there is no change in reference level when the EQUAL Switch is normal or depressed.

C. ZERO: Depress the ZERO Switch and adjust the ZERO Control to read a null on the voltmeter.

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VIII. ZERO SWITCH ADJUSTMENT

Filter Out

This procedure will ensure that depressing the ZERO Switch will insert into the Signal Channel a voltage having the same phase as the reference. This is done by adjustment of the broadband attenuator which samples the reference signal.

A. Connect Signal Generator output to reference and signal terminals.

B. Set FUNCTION Switch to "0°".

C. Set FILTER Switch to "OUT".

D. Set RANGE Switch to 1.0 volts.

E. Set FREQUENCY Switch to "KHz" and 3.16 to 10KHz.

F. Set Signal Generator to 8KHz and adjust output (no attenuation) to .6 volts. Set RANGE Switch to .1 volts (6 x overload).

G. Set REFERENCE LEVEL Switch to "LO", and adjust Reference Level Potentiometer to give approximately half-scale reading on Reference Meter.

H. Switch FUNCTION Switch to 90°. Voltmeter will read approximately a null.

I. Adjust ZERO Control for a null without depressing the ZERO Switch.

J. Depress ZERO Switch and adjust C308 for a null. (See Figure 6.2)

Filter-In Position

K. Place short circuit into filter sockets between Pins 2 and 8 of the octal socket.

L. Switch to filter IN position.

M. Adjust ZERO Control for a null without depressing the ZERO Switch.

N. Depress ZERO Switch and trim capacitor C102 on grid of filter in signal pre-amplifier V102 for a null (See Figure 5.2).

10Hz and 100KHz Adjustment

O. Repeat Steps A to H at 100KHz with FREQUENCY Switch in the appropriate position.

P. Depress ZERO Switch and adjust ZERO control for a null. Release ZERO Switch. Trim out offset, if any, at 10Hz by placing a high value resistor (5 to 30 meg) across input to signal or reference amplifier. Trim out effect, if any, at 100KHz by placing capacitor (nom. 25uuf) from the cathode of V101 or V301 to ground.

IX. REFERENCE HI-LO ATTENUATOR

This procedure will adjust the 30:1 reference input attenuator so that there is no phase difference between the HI or LO positions of the REFERENCE INPUT Switch.

A. Set FREQUENCY Switch to "KHz" and "1-3.16KHz" position.
Set Reference Level Control to full ccw.
Set FUNCTION Selector to 90° position.
Set RANGE Switch to 1 volt range.
Set FILTER IN-OUT Switch to "OUT" position.

B. Set Generator to 1.6KHz. Adjust output to give approximately half scale reading on the Reference Level Meter.

C. Null the voltmeter with ZERO Control without depressing ZERO Switch.

D. Switch REFERENCE HI-LO Switch to "HI" and turn Reference Level Control full clockwise. This should result in an on-scale reading of the Reference Level Meter.

E. Adjust C318 on Reference Preamplifier for a null on the voltmeter (VM-301A).

X. HIGH SIGNAL RANGE ADJUSTMENT

This procedure will adjust the 1000:1 signal input attenuator so that the attenuation is correct at all frequencies and there is no phase shift across the attenuator.

A. Set FREQUENCY Switch to "Hz" and "316-1000."

B. Set RANGE Switch to 3 volts.

C. Set FUNCTION Switch to 0^{o}.

D. Set REFERENCE Switch to appropriate position.

E. Adjust Signal Generator to 600Hz and full scale output reading on voltmeter (VM-301A).

F. Adjust Reference Level Potentiometer to give approximately half-scale reading on Reference Meter.

G. Adjust attenuator to give 3 millivolt output. Switch RANGE Switch to 1 millivolt position (3x overload).

H. Switch FUNCTION Switch to "90^{o}" position.

I. Null the VM-301A with the ZERO Control without depressing the ZERO Switch.

J. Switch RANGE Switch to 1 volt position and remove attenuation from Signal Channel.

K. Adjust C1301 mounted on RANGE Switch to bring voltmeter (VM-301A) to a null.

XI. RANGE SWITCH ARM CAPACITIVE TRIM

The purpose of this trim is to compensate for the difference

in capacitance of the RANGE Switch arm at 100KHz.

A. Set Signal Generator to 100KHz and 1.0 volt output out of the attenuator.

B. Set RANGE Switch to 300mv range (3 x overload).

C. Set FREQUENCY Switch to "KHz" and "31.6-100."

D. REFERENCE LEVEL Switch to appropriate position, Reference Level Control for mid-scale on Reference Level Meter.

E. Set FUNCTION Switch to 90°.

F. Null VM-301A without depressing ZERO Switch.

G. Attenuate signal by 40DB (10mv output).

H. Switch RANGE Switch to 3mv.

I. Null VM-301A with C1302 mounted on front deck of RANGE Switch.

XII. OVERLOAD ADJUSTMENT

This procedure adjusts the overload so that it starts to blink at 11 x overload.

A. Set FUNCTION Switch to "90°".

B. Set FILTER Switch to "OUT" position.

C. Set RANGE Switch to 10 millivolts.

D. Set FREQUENCY Switch to 3.16KHz range.

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E. Set REFERENCE Switch to appropriate position and Reference Control for half-scale reading on Reference Level Meter.

F. Apply an input signal of 110mv at 1KHz.

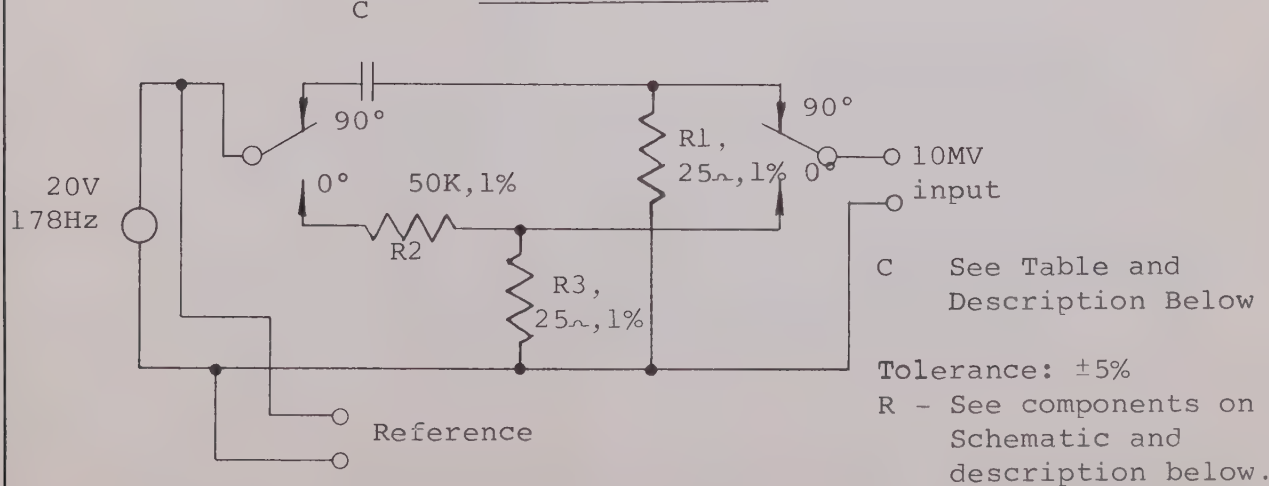
G. Adjust overload potentiometer (R1003) so that overload light just starts to blink.

H. Compare input voltage causing light to blink vs. voltage drop causing the light to extinguish. (Both should occur at the same point at all frequencies, 10Hz, 500Hz, 10KHz, 50KHz, 100KHz). It may be necessary to adjust R229 of Signal Amplifier Board for proper overload indication at 10Hz.

XIII. PHASE NETWORK ALIGNMENT

The purpose of this alignment is to calibrate the 90° phase shifters in the VM-301A. In order to do this, it is necessary to have precision 90° sources available at the various frequencies corresponding to the networks being trimmed. A simple circuit for generating this at one frequency is shown below. (More complete generation of other phase angles are shown in the phase generation circuits at the end of this section).

STANDARD NETWORK



C See Table and Description Below

Tolerance: ±5%

R - See components on Schematic and description below.

Since this network will pass harmonics of the signal frequency with less attenuation than the signal frequency itself, C must be a polystyrene condenser with a dissipation factor of less than 0.02%. This will allow a phase shift to within 0.011° of 90°. Care must also be taken to reduce the capacity across R2 to a minimum. For this purpose, it would be wise to use two separate toggle switches as shown above. For example, luuf across R2 can cause 0.18° of phase shift at 10KHz. For this reason, it is also best to use metal film resistors.

The following table shows values of C for the frequencies of alignment.

Band #	Freq.Band	Frequency	C (Std Network)	Component to be Trimmed on S6	Board 3 Terminals
2	31.6-100Hz	56.2Hz	.057 uf	C633	E-F
3	100-316Hz	178Hz	.018uf	C634	G-H
4	316-1000Hz	562Hz	.0057uf	C635	J-K
5	1-3.16KHz	1.78Khz	.0018uf	C632	C-D
6	3.16-10KHz	5.62KHz	.00057uf	R605	A-B

The procedure for alignment is as follows:

A. Set RANGE Switch to 1mv position (10 x overload).
Set FREQUENCY Switch to appropriate position for frequency to be calibrated.
Set FILTER IN-OUT Switch to "OUT" position.
Set FUNCTION Switch to 0° position.

B. Apply 20V (frequency to be calibrated) to the standard network and to the reference input terminals. Apply output of standard network to signal input terminals.

C. Set REFERENCE HI-LO Switch to "HI" position and set Reference Level Control to approximately mid-scale on the Reference Level Meter.

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D. Set the Standard Switches to the 90° position.

E. Null voltmeter with ZERO Control without depressing ZERO Switch.

F. Switch Standard Switches to the 0° position, and the FUNCTION Switch of the VM-301A to 90° position.

* G. If step F does not result in a null, then a trim component must be placed on the appropriate pins of S6, Board #3, as shown in the above table.

* H. This procedure must first be followed in Bands 2, 3, and 4, trimming C633, C634, C635, respectively. Band 6 must then be trimmed with R605. Finally, Band 5 must be trimmed with C632. The order for trimming must be followed carefully.

XIV. SPECIAL PHASE TRIM FOR INDIVIDUAL BAND

The phase network alignment procedure described in the preceding section results in the alignment of the 90° networks on all frequency bands. It is noted that each of the calibrations is done at the geometric mean frequency of the frequency band being aligned and the variation within the band is generally less than 0.1°. It is also noted that Bands 1, 7, and 8 are not trimmed at all. No trimming is necessary on these bands because trimming bands 2, 3, 4, 5 and 6 will automatically calibrate bands 1, 7, and 8. Due to the nature of the special networks and switching used, the calibration of one band will somewhat affect others.

In certain applications it may be desirable to calibrate a particular frequency or band without affecting the complementary band associated with it. Thus, the instrument has been designed to provide a means for inserting a phase trim on any four of the eight bands, provided that the ones trimmed are not complementary. That is, either bands 1 or 5, 2 or 6, 3 or 7, and 4 or 8. If the instrument is so calibrated (by request) the procedure for changing or readjusting this trim follows.

*In later instruments, these trims are located on TB6-A (see Page 4.33).

It will be noted that S6, Board #3 uses six terminals, which are marked N, P, S, T, U, V. (Terminals Q and R are intermediate and included for the sake of convenience). These terminals are connected by means of the FREQUENCY Switch so as to allow the special band trimming noted above.

NOTE: Before attempting this trim, re-read carefully Phase Network Alignment Procedure in the preceding section.
(Do not touch previous network trims).

1. Using the standard test network outlined above, select values of C and R1 that will give 10mv output and 90° phase shift at the desired frequency (or band) using band 1 (10Hz to 31.6Hz) as an example.

2. Follow the alignment procedure outlined in the manual on Page 5.13 Steps A through F.

3. To bring the VM-301A to exact null, temporarily connect a capacitor or resistor as needed between terminals R and S, Board #3.

4. After selecting the proper value in Step 3, permanently install this component between Terminals R and S.

5. The procedure used in Steps 3 and 4 above may be used in any of the bands using terminals S, T, U or V and Terminal R consecutively for trimming bands 1, 2, 3, 4 respectively.

6. The high bands are trimmed in the same manner except Terminal Q is used in place of Terminal R. Pins S, T, U, or V may be used to trim bands 5, 6, 7 or 8 respectively.

NOTE: HI or LO bands may be trimmed, but not both simultaneously.

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XV. PHASE POTENTIOMETER TRIMMING

This trim is necessary to compensate for the effects of capacity to ground on the phase potentiometer arm. This effect is a maximum when the Phase Dial is at 45° and the frequency is at the upper end of the Hz and KHz ranges.

A. Set the FREQUENCY Switch to "Hz" and "316-1000."
Set FUNCTION Switch to 90°.
Set FILTER IN-OUT Switch to "OUT" position.

B. Set Signal Generator to 1000Hz and connect it to reference terminals and through zero phase attenuator (66DB) to signal input. Adjust signal generator for 20V output.

C. Switch RANGE Switch to 1mv range (10 x overload).

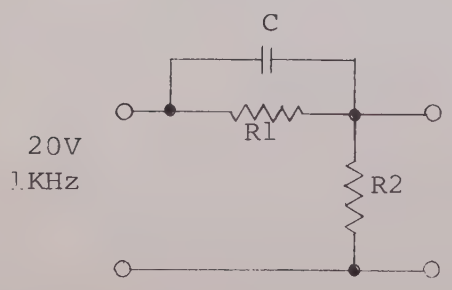
D. Set REFERENCE Switch to "HI" and adjust reference level control for mid-scale reading on Reference Level Meter.

E. Adjust "EQUAL" control as accurately as possible.

F. Adjust VM-301A for null with ZERO control without depressing ZERO Switch.

G. Disconnect the signal generator from the attenuator and connect it to an accurate 45° ± 0.05 network, which has an output of 10mv. A network of this sort is shown below. Connect the output of this network to the signal input terminals.

H. Rotate Phase Dial to 45°, and adjust C645 for a null on the voltmeter.



C - .003uf ±0.1% Polystyrene
Dissipation Factor is .02%.
R1 - 53.11K±0.05% Metal Film.
R2 - 22Ω ±1% Metal Film.

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XVI. PHASE DIAL ALIGNMENT ON PHASE SHIFTER POT, R8

The following is a procedure for mechanically aligning the Phase Dial on the shaft of the phase shift pot (R644). This is necessary in the event that a Phase Dial, a phase pot, or both are disassembled or replaced. (See Figure 4.19 for disassembly instructions). The 0° and 90° points on the dial must be aligned to coincide with the taps (terminals 4 and 5) of the pot.

CAUTION: Use only a high impedance ohmmeter (i.e., H.P 412) as damage to the precision phase pot can occur if excessive voltage is applied.

A. Turn power off.

B. Set FUNCTION Selector to any phase sensitive position.

C. Use an ohmmeter to place the wiper (Terminal 2) of R644A exactly on the ccw (terminal 4) tap point. Loosen dial clamping screws and rotate Phase Dial until dial reading is exactly 90°. Tighten clamping screw. Reconnect ohmmeter to CW (terminal 5) tap point and rotate Phase Dial until wiper of R644A is on cw tap point. Dial should now read zero degrees. If not, reposition dial so as to achieve the best compromise reading between the two taps. For example, if the zero degree point reads low, the 90° point should read high by the same amount. Check the 0° and 90° alignment of R644B in the same manner without slipping the dial on the pot shaft

The maximum error should not exceed .05° on the Phase Dial. All errors should be divided equally between all 4 tap points. Fully tighten the set screws and recheck to make sure dial has not slipped during tightening.

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XVII. Phase Angle Generation

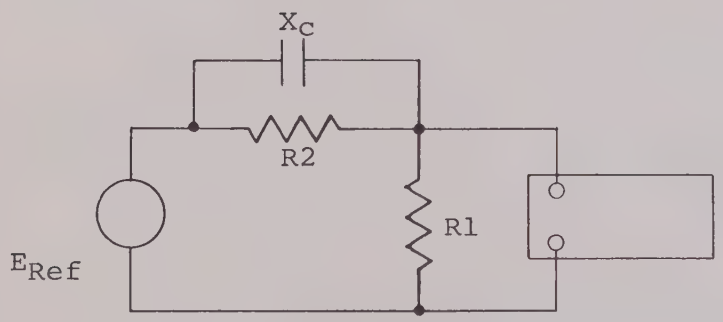
The test procedure requires that phase angles other than 90° or 0° be used for some checks. Commercially available phase angle generating equipment may be used to perform these tests. However, if commercial equipment is not available, it is suggested that the following methods be used.

RC Passive Phase Shifter - Precise phase angles can be generated using the circuit configuration shown below. These networks are very useful and are simple to construct. They do require, however, accurate measurement of component values. They may be constructed with the aid of the design equations shown below. The components should be high quality, stable devices; such as, mica or polystyrene capacitors, and metal film or deposited carbon resistors.

$$\text{Attenuation} = \frac{R_1}{|Z|}$$

$$\text{Phase Shift} = \text{Tan}^{-1}\ \frac{R_2}{X_C}$$

Providing $R_1 \angle \angle |Z|$



$$Z = \frac{R_2}{1+j\ \frac{R_2}{X_C}}$$

$$|Z| = \frac{R_2 X_C \sqrt{X_C^2+R_2^2}}{X_C^2 + R_2^2}$$

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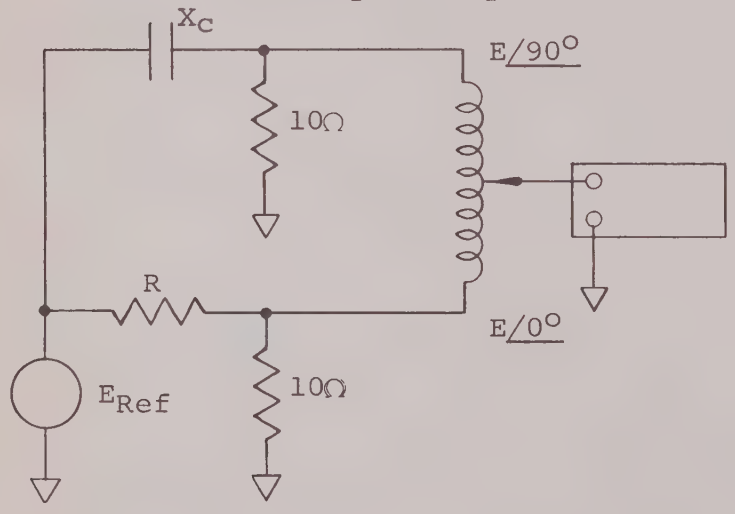
Ratio Box Phase Shifter - This circuit is somewhat less complicated than the previous circuit in that it requires only a precise 0° and 90° signal be generated by use of passive networks but it does require that a high quality Ratio Box which is accurate at the operating frequency be used. The components again must be high quality and drift free. It may be seen that any angle between 0° and 90° can be selected depending on the setting of the Ratio Box. It should be noted, however, that the amplitude of the 0° and 90° signal should be set equal to each other. The output amplitude will vary through a minimum of 0.707 of the 0° and 90° signals at 45° (Ratio Box setting of 0.5).

Phase network component values and Ratio Box settings are determined by the equations shown.



$$\frac{X_C}{10} >> 1000$$

$$R = X_C$$

$E\angle 0^{\circ}$ and $E\angle 90^{\circ}$ must be set equal within 1/4%.

$$\text{Ratio Box setting} = \frac{1}{1+\text{ctn}\theta}$$

where θ is desired phase shift.

Resolver Simulator Phase Shifter - The third system is that of the resolver simulator phase shifter. This circuit very closely simulates the performance of the resolver in that the phase angle generated is between 0° and 90° at a constant amplitude. The same passive networks as above are used to generate the 0° and 90° and also as above their amplitudes must be set equal to each other. Two Ratio Boxes are used to drive a bridging transformer. The 0° and 90° signals of varying amplitudes as set by the Ratio

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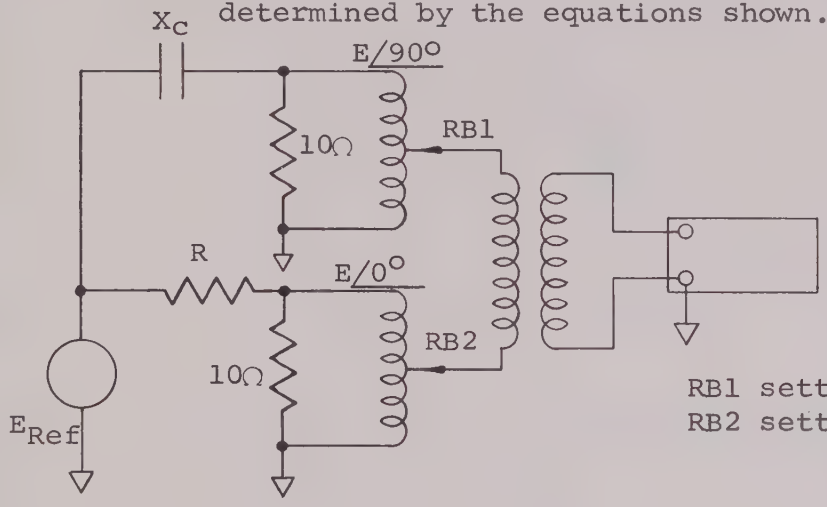
Boxes are then summed vectorally in the bridging transformer and the resultant output is fed to the Model 301A. Phase network component values and Ratio Box settings are determined by the equations shown.



$\frac{X_C}{10} >> 1000$

$R = X_C$

E/0° and E/90° must be set equal within 1/4%.

RB1 setting = sin θ
RB2 setting = cos θ
} where θ is desired phase shift.

NAI Model 350 Phase Generator

The Model 350 Phase Generator uses the same technique as the latter, above-mentioned system packages in one convenient instrument. Front panel controls, calibration in phase angle permit direct selection of phase angles, avoiding the necessity for computing component values and ratio box settings. The frequency range of the instrument is 50Hz to 12KHz.

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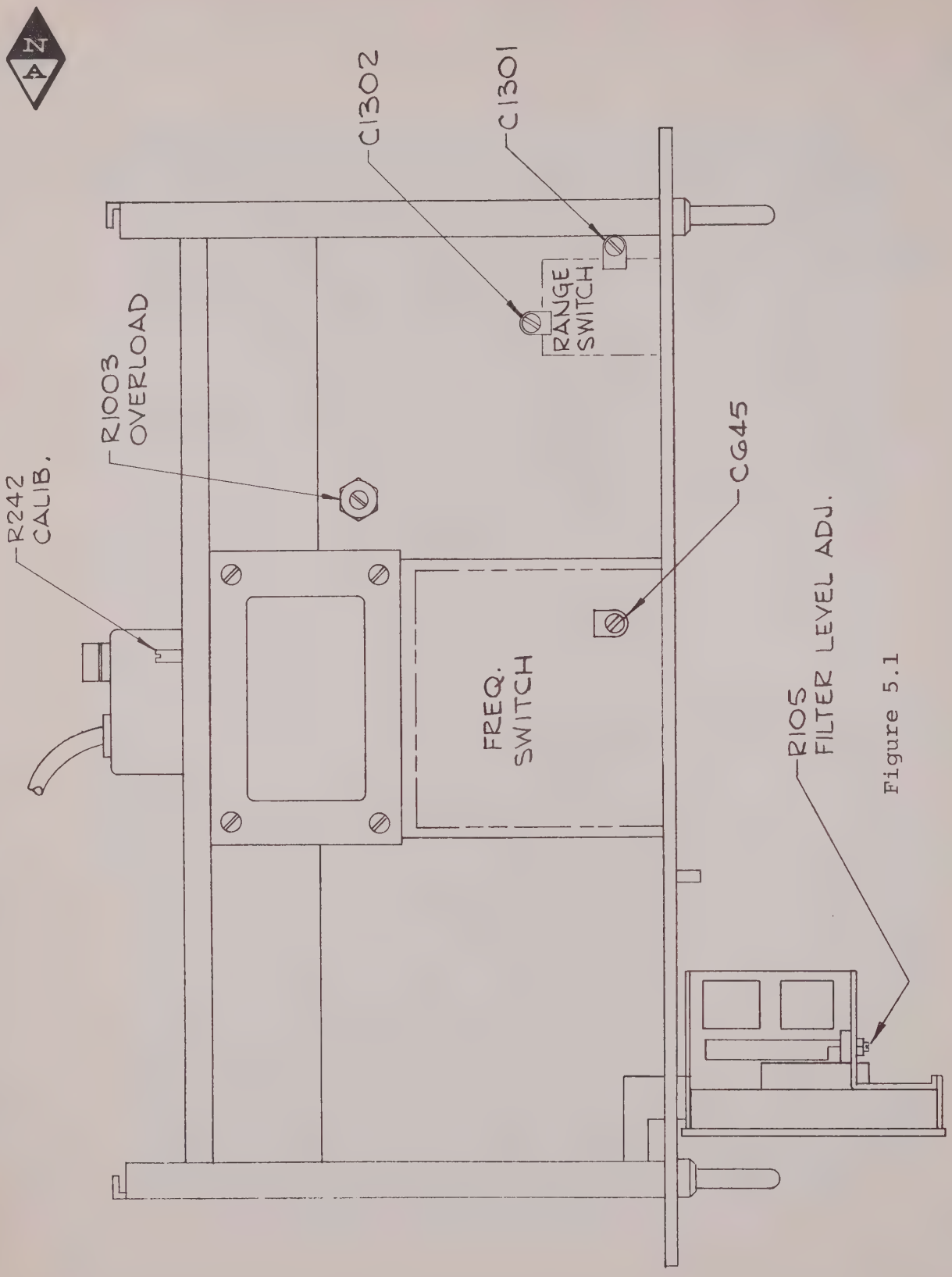
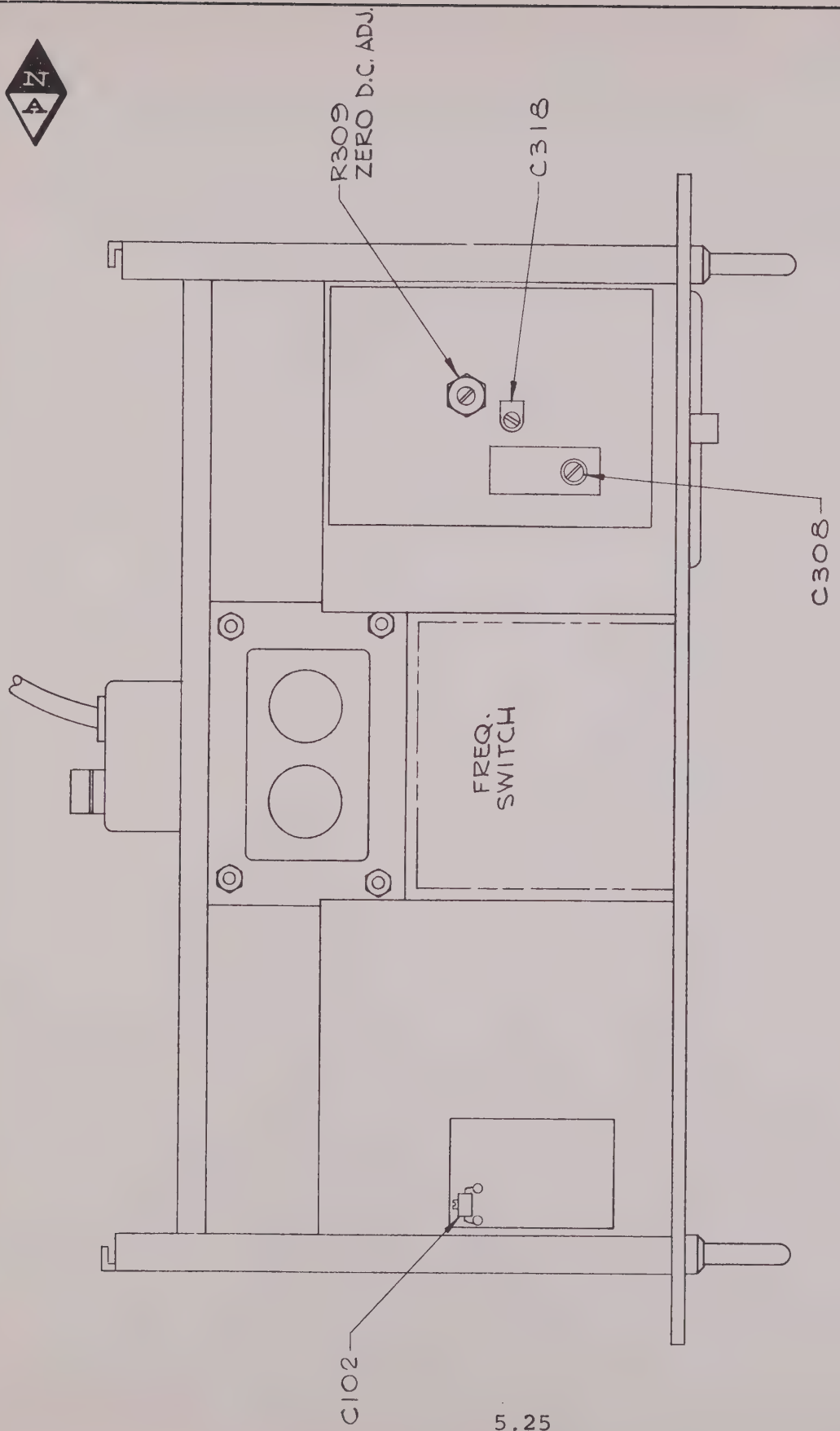


Figure 5.1

TOP VIEW



BOTTOM VIEW

Figure 5.2

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SECTION VI

MODIFICATIONS

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

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9/66

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WARRANTY

North Atlantic Industries, Inc. warrants its products against defects in material and workmanship for one year from the date of the original shipment. Our liability is limited to repairing or replacing products (except fuses and electron tubes) which prove to be defective during the warranty period.

North Atlantic Industries, Inc. is not liable for consequential damages or for any damage or injury to persons or property resulting from the operation or application of any of its equipment.

Warranty is voided if there is evidence that the product has been operated beyond its design range, improperly maintained, or physically mistreated.

In the event of a malfunction in a product under warranty, the purchaser should notify his local Sales Representative or the Sales Department of North Atlantic Industries, Inc. giving full details of the defect and providing the model and serial number of the instrument. Service data or shipping instructions will be forwarded promptly. There is no charge for warranty repair of products, except transportation charges.

North Atlantic Industries, Inc. reserves the right to make changes and improvements in its products without any liability for incorporating such changes or improvements in any products previously sold.

No other warranty expressed or implied is offered other than the foregoing.

Estimates of charges for out of warranty repairs or other service work will be supplied before work begins. Out of warranty repairs will only be made following the receipt of purchaser's authorization of applicable charges.

Claims for Damage in Shipment

The purchaser should inspect and functionally test the product in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or, if insured separately, with the purchaser's insurance company.

(turn over for Shipping Instructions)

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Shipping

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in heavy paper or a plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

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under the terms of the warranty stated in this Instruction Manual.

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Company _____

Address _____

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Calibration and maintenance responsibility has been assigned to the following person and/or department. Address applicable service data to (if same as above, please state):

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Title _____ Dept. _____

For our information please indicate:

Condition of instrument on receipt _____

Application _____

Will the instrument be: resold as part of a system? _____

maintained as company equipment? _____

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APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter, and a power factor meter.

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I - INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instrument's ability to measure the two basic characteristics of any signal; namely, magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure (1).

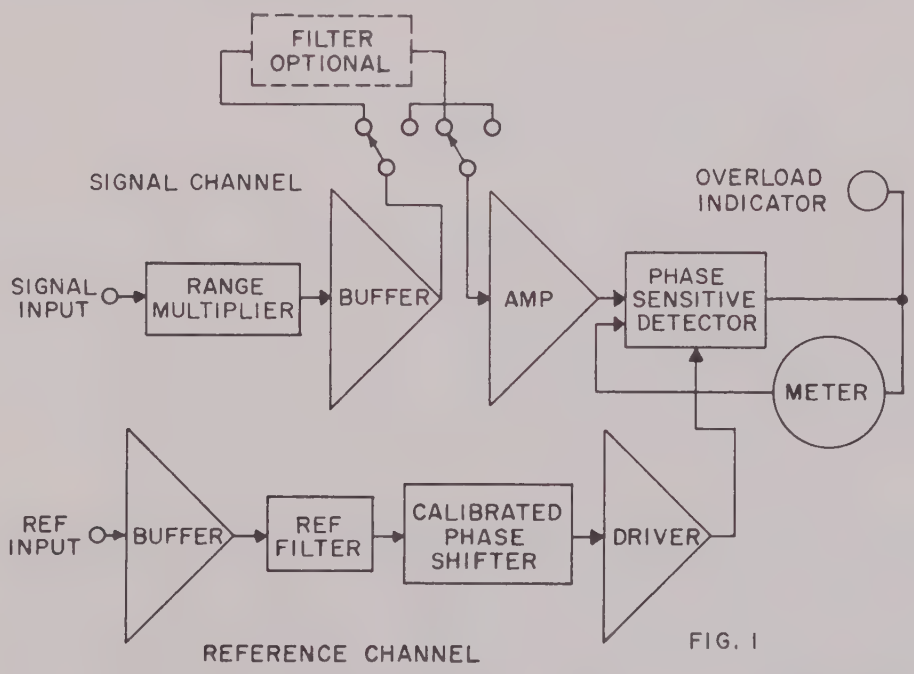

FIG. 1

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an AC signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures (5) and (6).

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The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II - GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

a) Internal noise
b) Electrostatic pickup
c) Inductive pickup
d) Common ground runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

Electrostatic pickup, frequency a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads one of which is at ground potential. Care must be taken, however, to avoid loading the signal source by the cable capacitance.

Inductive pickup is generally less often encountered than electrostatic pickup and possibly for that reason, methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that

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portion of a circuit where a measurement is being made. Figure (2) shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure (2A) is the most advantageous arrangement and is not at all critical to lead runs. Figures (2B) and (2C) both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure (2) can exist due to chassis contact, line cord ground, and reference grounds. All must be considered when setting up the measuring system.

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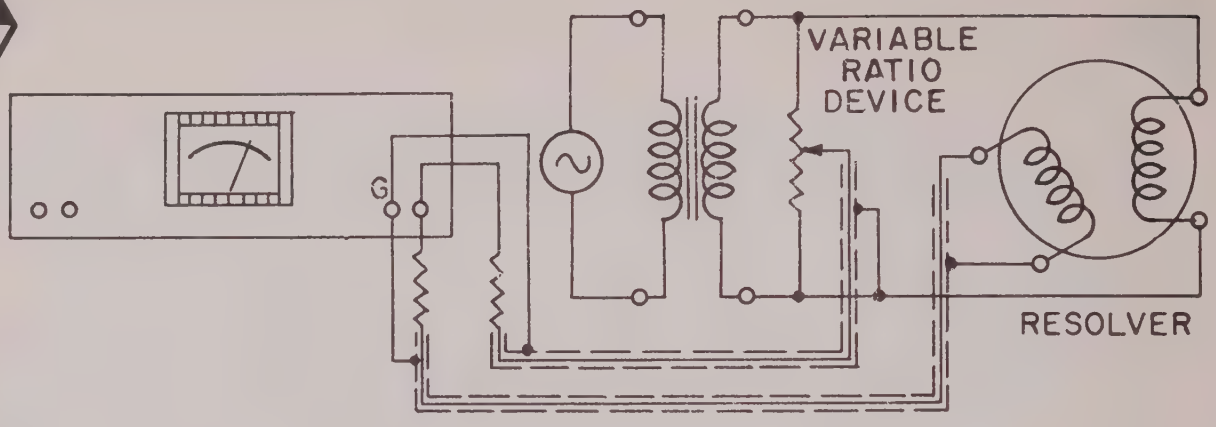
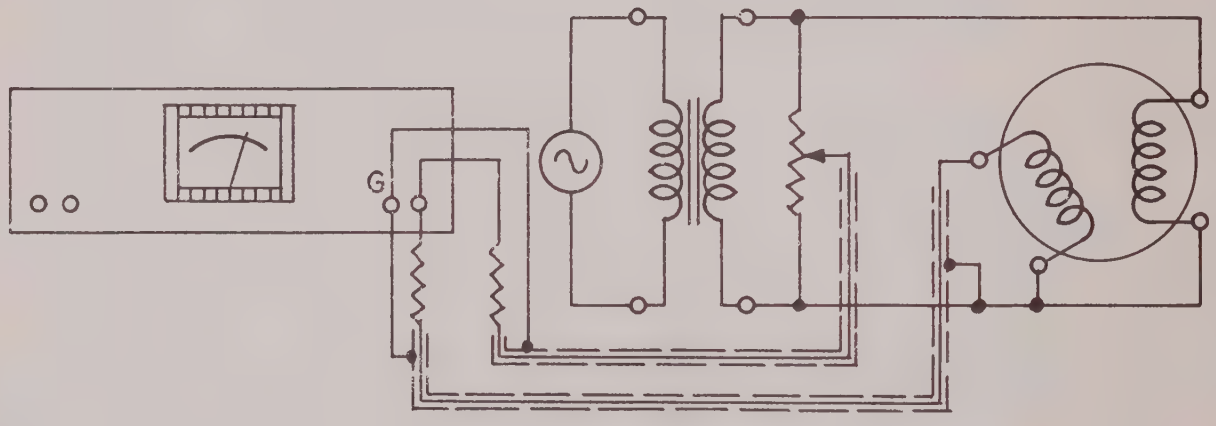
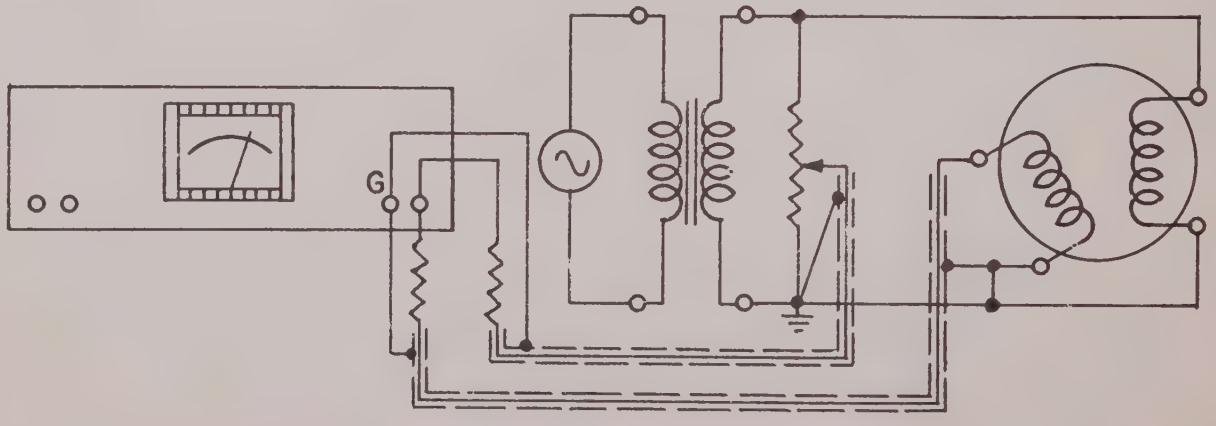


(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

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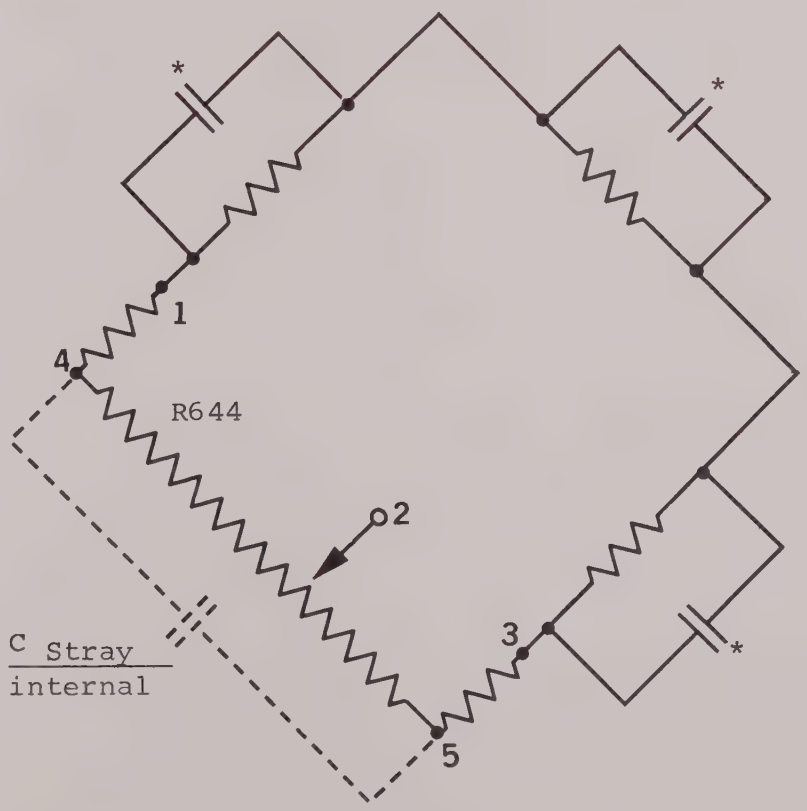
ADDENDUM

Phase Pot Trim

R644A and R644B are used to select phase angles in the Model 301A. Due to the circuit configuration, internal capacity between the tap points of the pot has a significant effect on the accuracy of the circuit. This effect is trimmed out by adding shunt capacitors across the three fixed resistors in the bridge. The value of these capacitors will be between 0 and 150uufd (approximately equal to the stray capacity in the pot).



*Factory selected at test.
NOTE: Some units may require no trim.

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ERRATA SECTION

PAGE 1.6:

Phase Accuracy: Using Calibrated Phase Dial:
1. ± 0.25° from 31.6Hz to 31.6KHz.
2. (31.6KHz to 100KHz: Gradual degradation to ± 1° at 100KHz as frequency is increased).
3. (Gradual degradation to ± 0.6° as frequency is decreased).

10/12/67

PAGE 1.7:

Noise (VTVM): Less than 20 microvolts in "Filter Out".
Less than 30 microvolts in "Filter In".

10/12/67

PAGE 2.10:

4. Set PHASE Dial to "0 degrees" and FUNCTION Selector to "0 degrees".

10/12/67

PAGE 4.2:

TUBE REPLACEMENT

B. When replacing V201, it will be necessary to monitor the plate voltage of V202. This is at the top of R212 (5.6K, 1/2W resistor) located directly under the V202 tube socket on the 500047 (Signal Amplifier) components board (Figure 4.2). A V201 (6BH6) tube should be chosen so that this voltage will be 150 ± 15 volts to ground, or trim R207 for 150 ± 15 volts after selecting a tube that will result in a voltage close to 150V.

10/12/67

Addendum #104

PAGE 4.3:

D. Several resistors in the voltmeter are precision components. If these resistors require replacement, use the same value and type as the original. If different values are used or components are moved, calibration or frequency response may be affected and re-adjustment may be required. Be careful to replace components as closely as possible in the same position the original components occupied. Pay careful attention to wiring and do not reroute or move any of the wires.

10/12/67

PAGE 4.9:

Change the replacement parts list as follows:

R206	Resistor, Fixed, Comp., 82K, 1W, ±5%	NAI #801529
R215, R229	Resistor, Fixed, Comp.	Select at test

10/12/67

PAGE 4.10:

Omit R229 from parts list on this page.

10/12/67

PAGE 4.11:

Change the Parts list as follows:

R239, R240	Resistor, Fixed, Dep. Carb., 140Ω, 1/2W, ±5%	NAI #802376

10/12/67

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PAGE 5.2:

II. NOISE CHECK (filters must be plugged in before proceeding).

With signal input shorted in the vtvm position, noise as read on the meter shall be as follows:

Filter OUT 20uv max. Null _____

Filter IN 30uv max. Null _____

III. NULL CHECK

With input shorted (reference connected) Phase Sensitive Mode, output meter should read:

Up to 31.6KHz, 2uv max. Null _____

31.6KHz to 100KHz, 10uv max. Null _____

10/12/67

PAGE 5.7:

Power Supply Alignment (should read):

Pin	DC Volts	AC VTVM
*10	-79 to -81	Approx. 600uv
11	+260 to +270	Approx. 1mv
12	+175 to +200	High 10-20 volts
15	+250 to +270	Approx. 9mv
9	+12 to +12.6	Approx. 3mv
7	Ground (tied to Signal Ground in Signal Amp.)	
16	-120 to -140 volts	200mv approx.

..continued..

10/4/68

PAGE 5.7 (continued)

Pin	DC Amplitude Adjust	Ripple Adjust
10	R908 (27K nom.)	R912 (33K nom.)
11	R938 (1.2K nom.)	R937 (240K nom.)
7	R930 (39K nom.)	No Adjust.

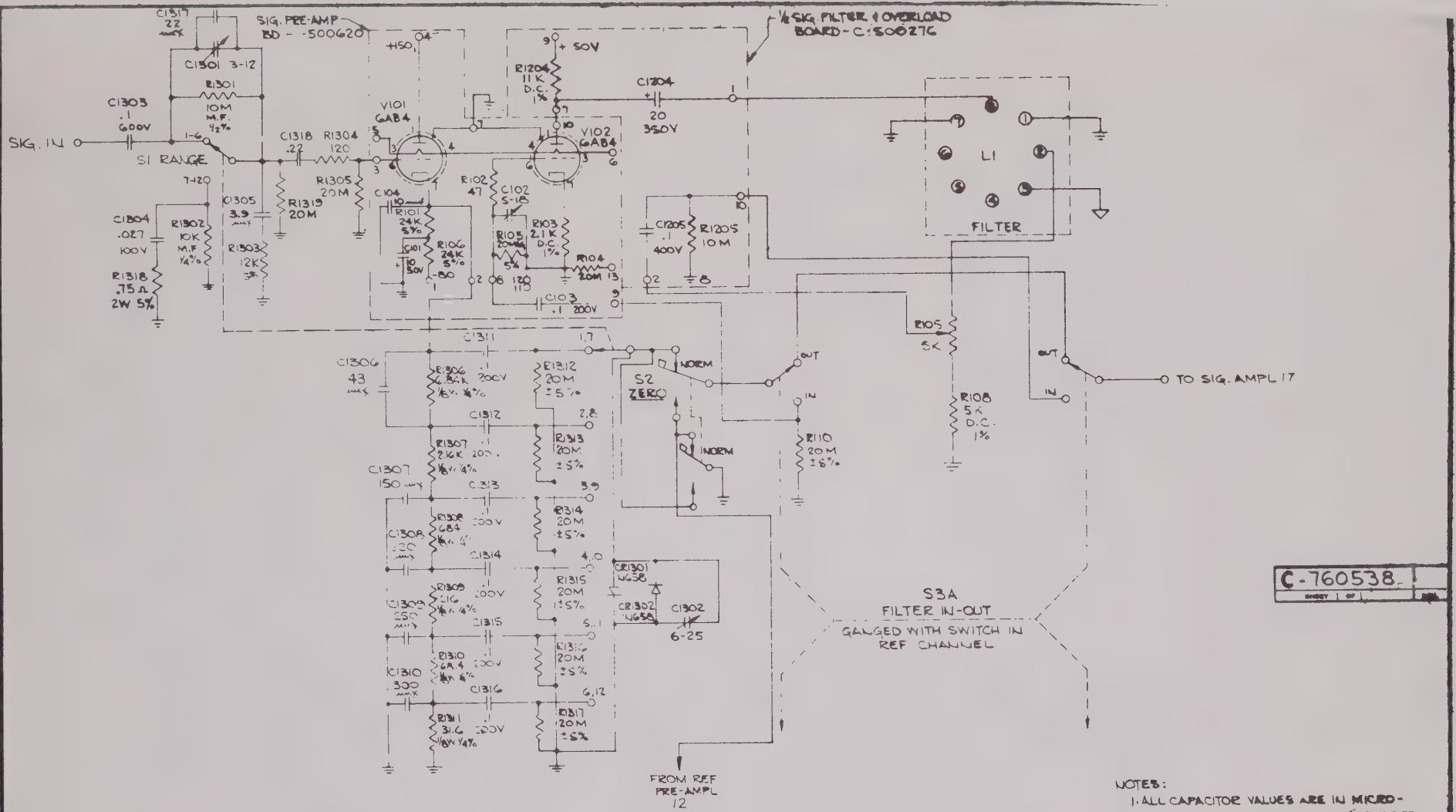
Explanation:
The resistor values indicated are nominal values only. They should be selected to produce the desired voltages - i.e., R938 may range from 200Ω to 2K.

10/4/68

PAGE 5.11:
(Should read)

VIII J. Depress ZERO Switch and Adjust C308 for a null. (See Figure 4.3).

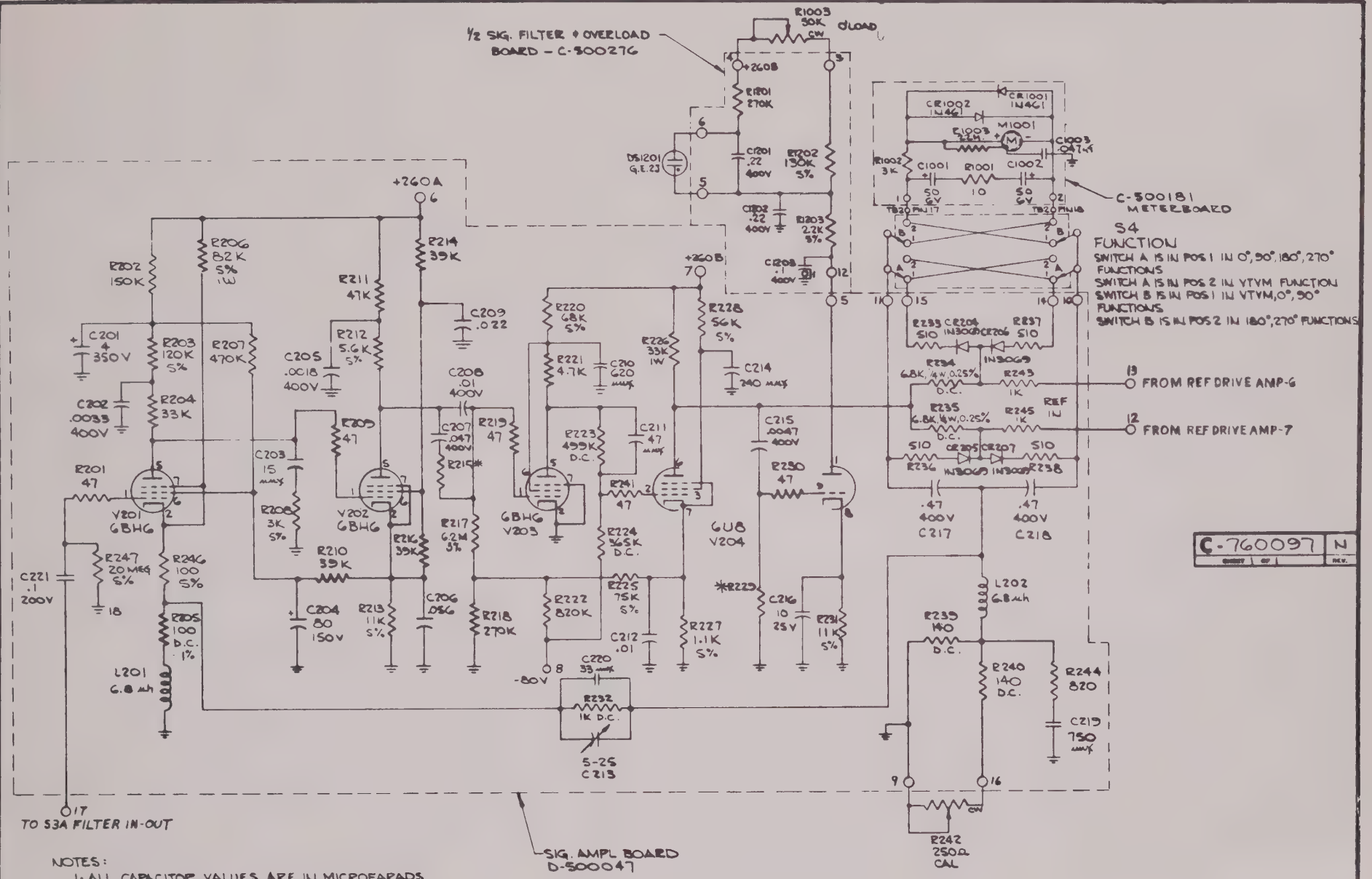
8/19/68



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½ W, ±10% UNLESS OTHERWISE SPECIFIED

SIGNAL PREAMPLIFIER
Figure 3.2
Page 3.4

Revision A - 10/17/67
Revision B - 10/4/68



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½ W, ±10% UNLESS OTHERWISE SPECIFIED

*Select at Test

SIGNAL AMPLIFIER
FIGURE 3.3

Revision A - 10/17/67

Common ground runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure (3) is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure (3) also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

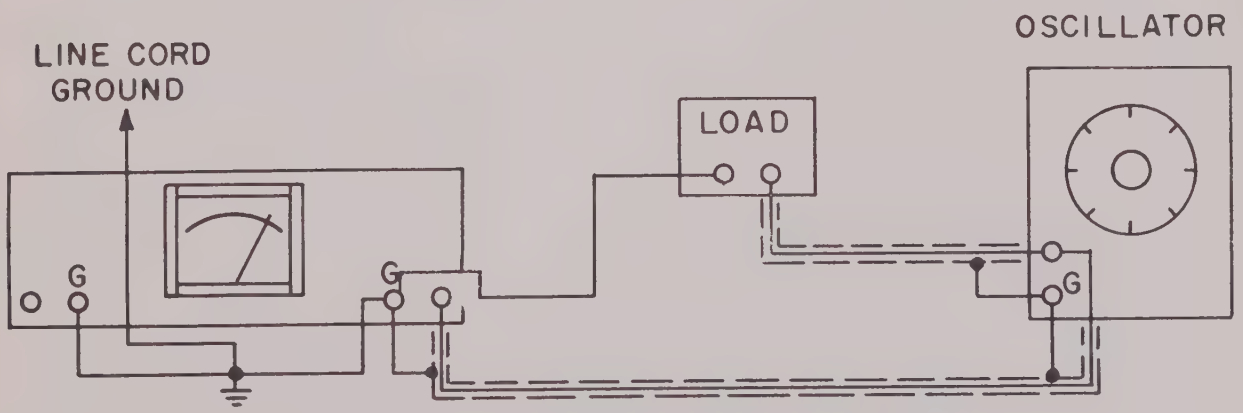


FIG. 3

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III - PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E_{meter} = E_{rms} \times \cos \theta$

where E_{meter} = voltage read on the meter
E_{rms} = rms value of the input sine wave
θ = angle between the reference and signal input (Phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

(2) $$E_{meter} = \frac{E_{rms\ (3rd\ harmonic)} \times \cos \theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55DB down. Table I shows typical measured responses. The values shown with filters actually are the sum of the colum I data and the filter characteristic.

TABLE I

FUND (400cps)	No Signal Filter 0DB	With Signal Filter 0DB
2nd Har.	-55DB	-55DB
3rd Har.	-9.5DB	-55DB
4th Har.	-55DB	-55DB
5th Har.	-14DB	-55DB

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Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the setup dhown in Figure (4). The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the θ = 90 deg. and the θ = 0 deg. point. Measurement than will be a voltage which can be directly translated into degrees using the curves of Figures (5) and (6).

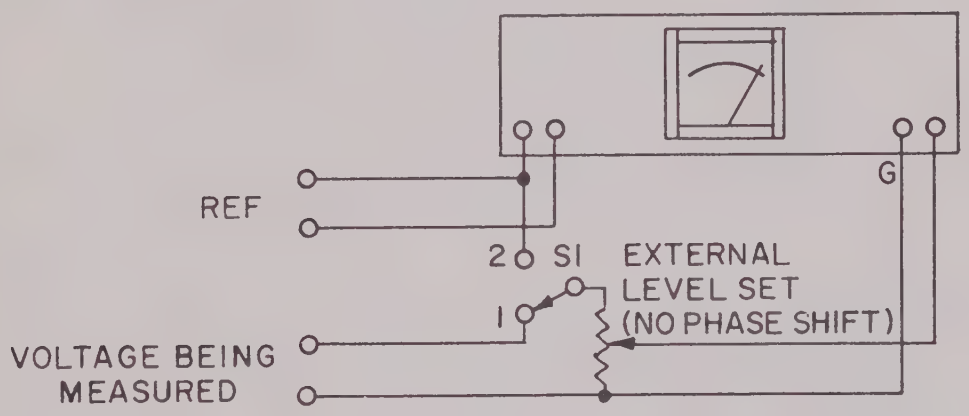

FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (NOTE: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.)

3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection.

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Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the θ = 0 deg. point or quadrature null point.

NOTE: FOR MAXIMUM ACCURACY, THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the θ = 90 deg. point (E maximum).

5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure (5) or (6) to read degrees.

Any full scale range in degrees can be used even down to -6 deg. - 0 - +6 deg, depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4deg. - 0 - +17.4 deg. Table II summarizes typical setups and Figures (5) and (6) show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously, this condition is a function of reference level and for that reason, a level of twice the red line value is recommended when using this technique.

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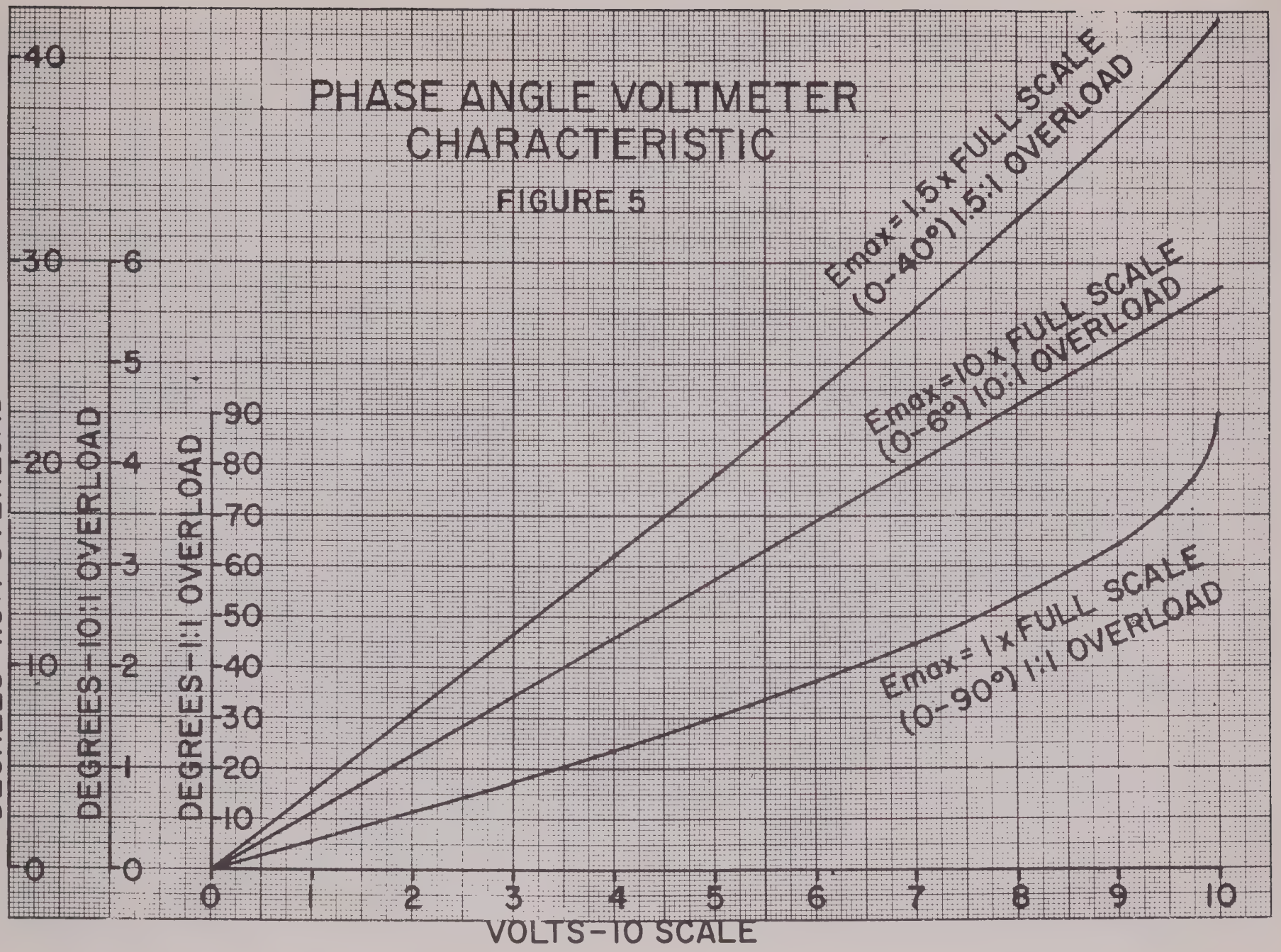
PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 5
Emax=1.5x FULL SCALE
(0-40°) 1.5:1 OVERLOAD
Emax=10x FULL SCALE
(0-6°) 10:1 OVERLOAD
Emax=1x FULL SCALE
(0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE
0
10
20
30
40
1
2
3
4
5
6
7
8
9
10
90
80
70
60
50

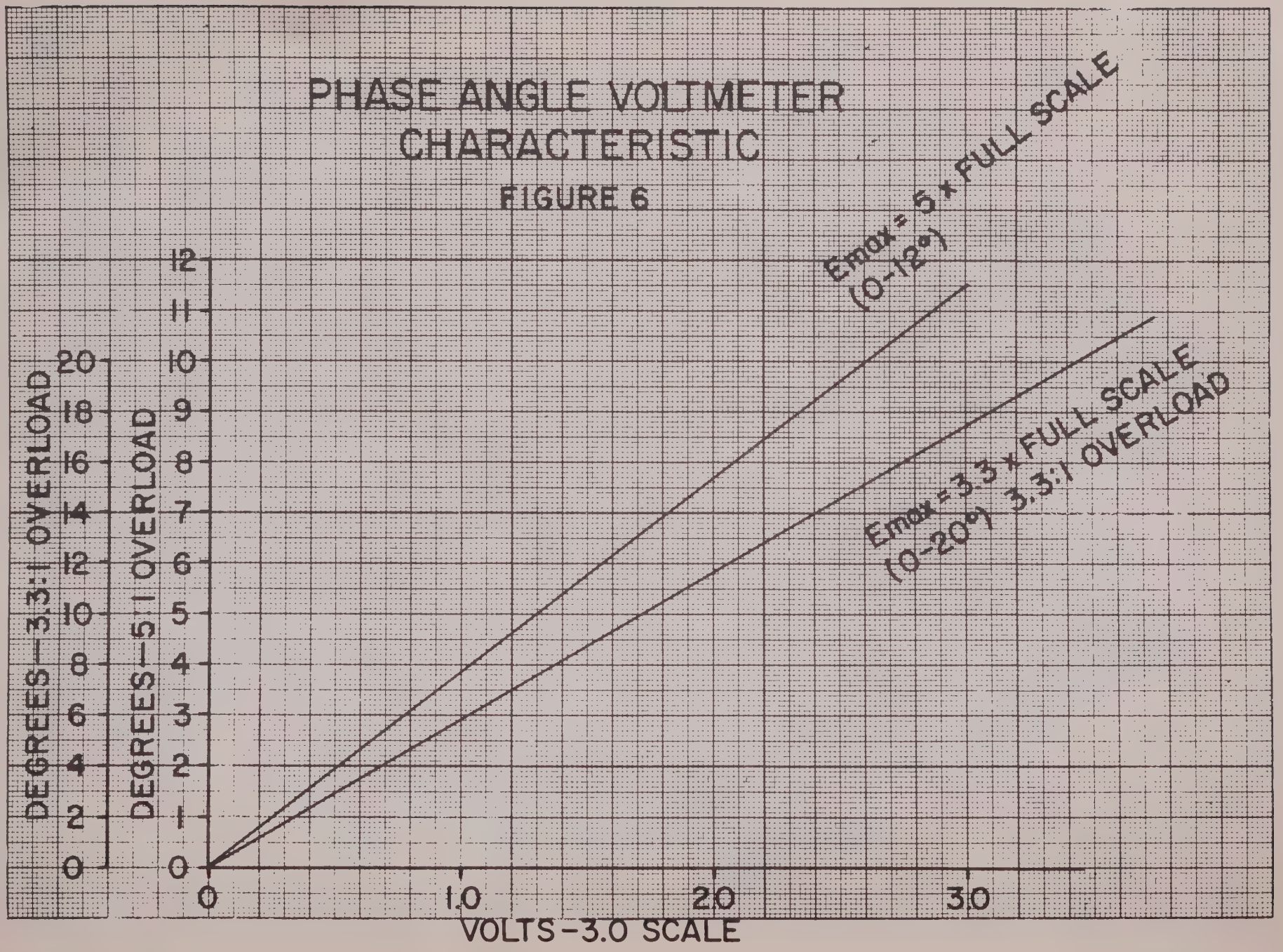
PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 5 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
DEGREES — 3.3:1 OVERLOAD
DEGREES — 5:1 OVERLOAD
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
5
6
7
8
9
10
11
12
0
1.0
2.0
3.0
VOLTS — 3.0 SCALE

TABLE II

Maximum Voltage	Scale for Measuring Degrees	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	90	2.7 deg.	5
1.0	.3	3.3:1	19.5	0.6	6
1.0	.1	10:1*	5.7	.2*	5
1.5	1.0	1.5:1	41.8	1.3	5
1.5	.3	5:1	11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than .01° can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV - PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built-in, calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees, the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

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This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V - MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

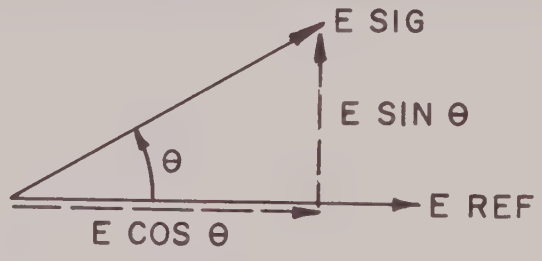

FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure (7) as:

In-phase component = E cos θ

Quadrature component = E sin θ

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be E cos θ. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage E sin θ. For the greatest accuracy in this type of measurement, the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI - MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This

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measurement is conveniently accomplished by means of the set up shown in Figure (8). The angle is measured as previously discussed.

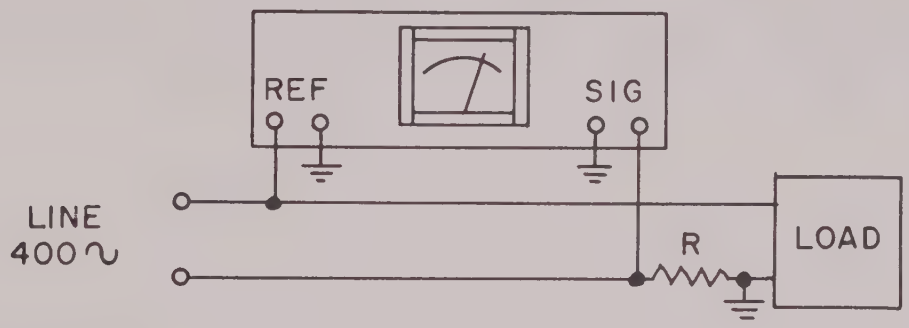

FIG. 8

VII - IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure (9) illustrates the manner in which the measurements can be made.

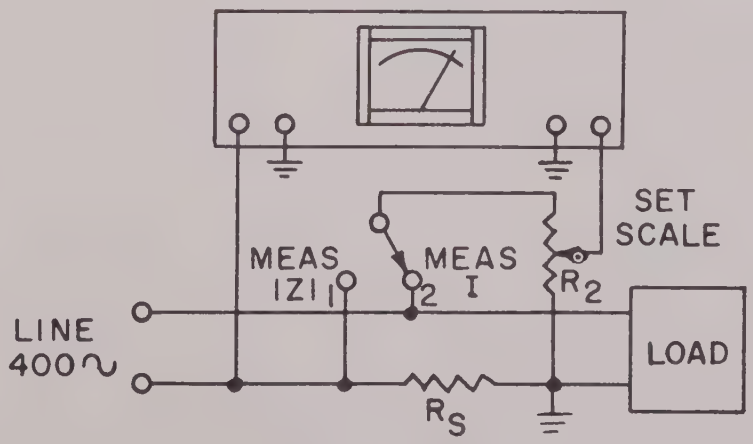

FIG. 9

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Using Table III as a guide, a precision ($\pm$ 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale voltage on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE:

Load impedance = 470K
Rs = 1K
E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1V equals	Current Factor
10K	10K	1/volts
1K	1K	1/volts
100Ω	100Ω	1/volts
10Ω	10Ω	1/volts
1Ω	1Ω	1/volts

Measurement of AC Resistance and Reactance

By using the circuit of Figure (9) the real and imaginary components of the impedance can also be measured directly by using the current as a reference and measuring the in-phase and quadrature of the signal measured with the switch in position 2. The in-phase component will be the AC Resistance and the quadrature component will be the reactance with the sign determined as positive for a

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right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII - APPLICATIONS

Precision Ratiometer

In many analog computer systems the process of multiplication, division, addition, and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure (10) permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

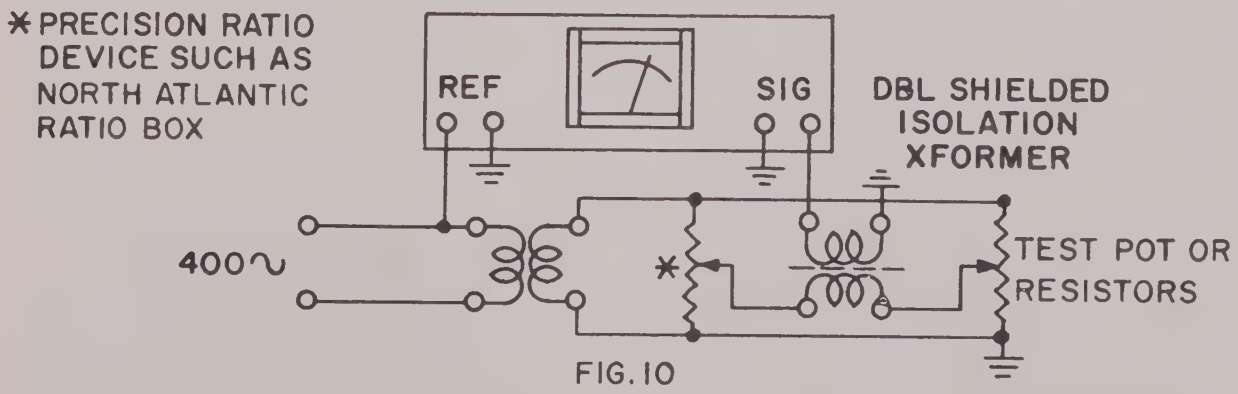

FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance

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transformer such as North Atlantic's T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

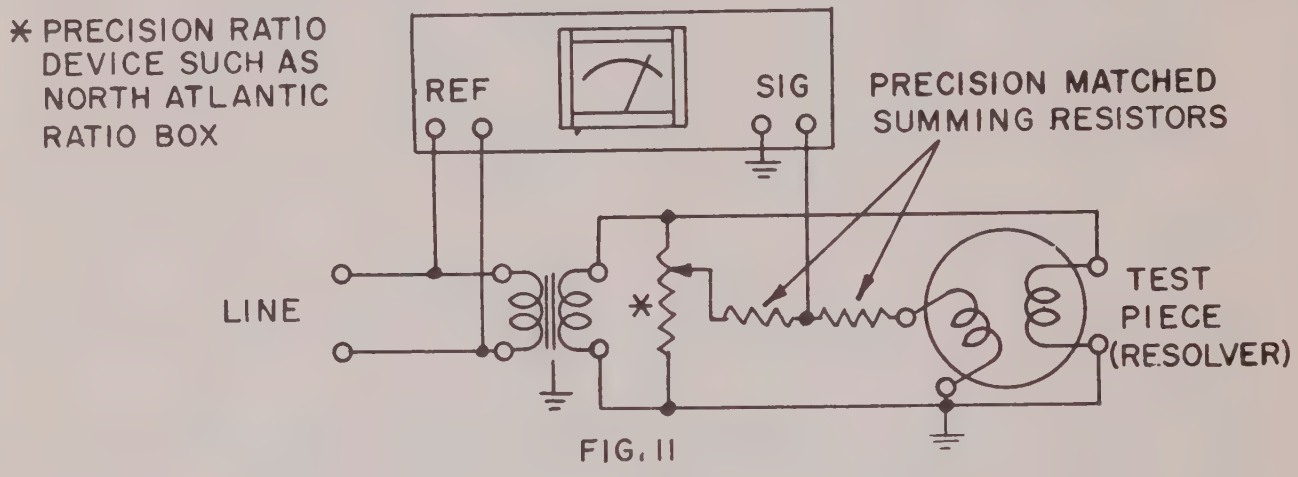

FIG. 11

Transducer Nulling

Applications involving transducers, such as differential transformers or E-Coil pickoffs, are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure (12) shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

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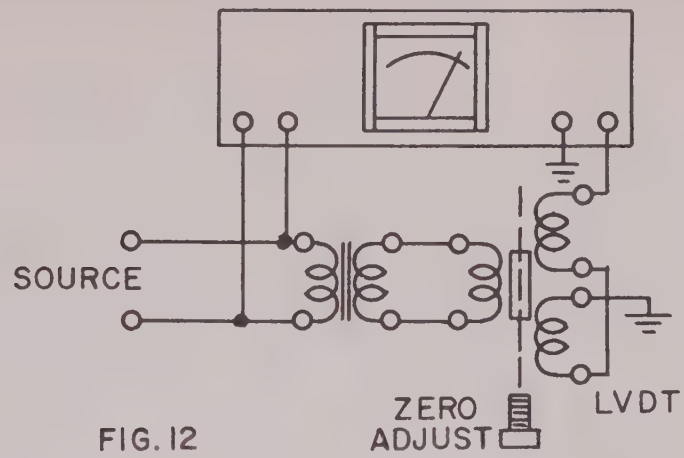

FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure (13) is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible nulls obtainable by conventional instrumentation.

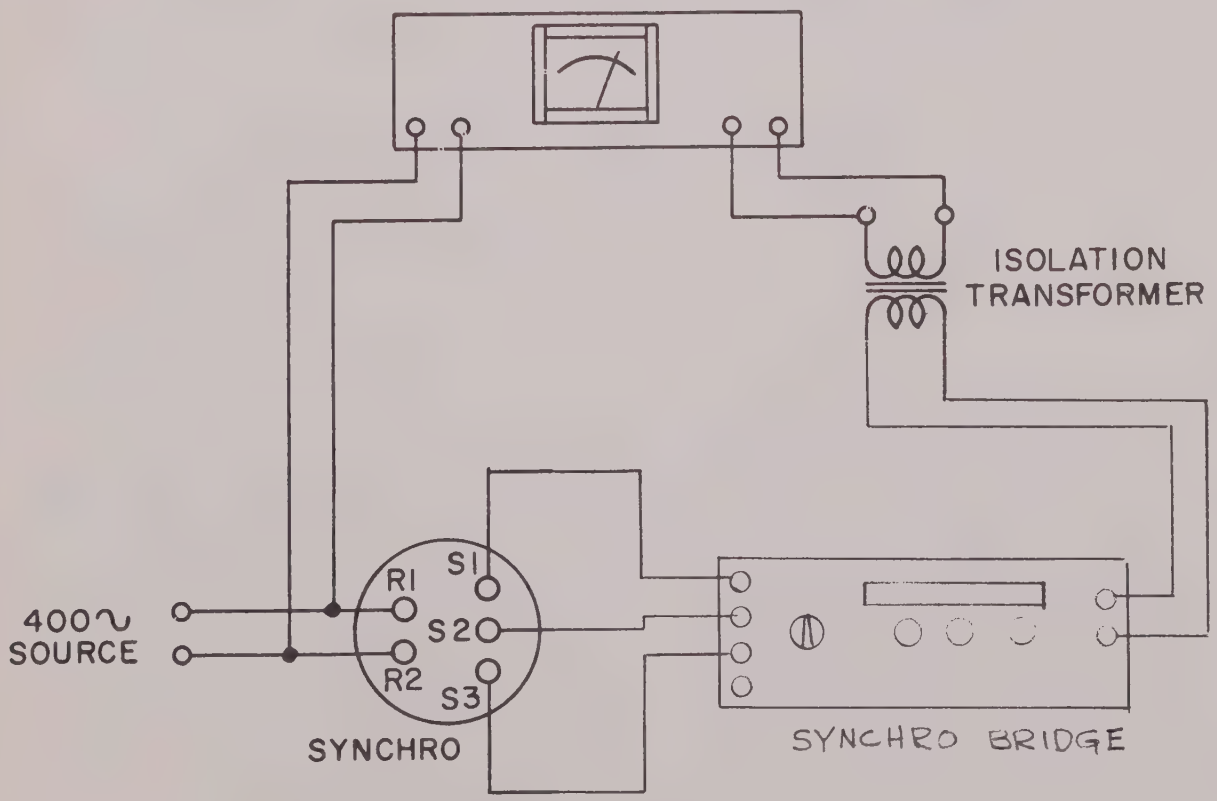

FIG. 13

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Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped waveforms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure (14) the task of alignment for maximum torque or output is straightforward since the meter reading is equivalent to motor output.

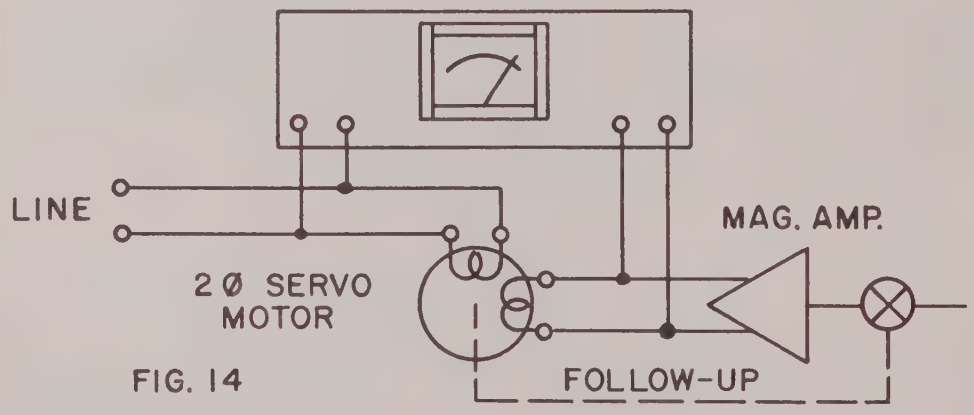

FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc., must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure (15) is a test setup used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

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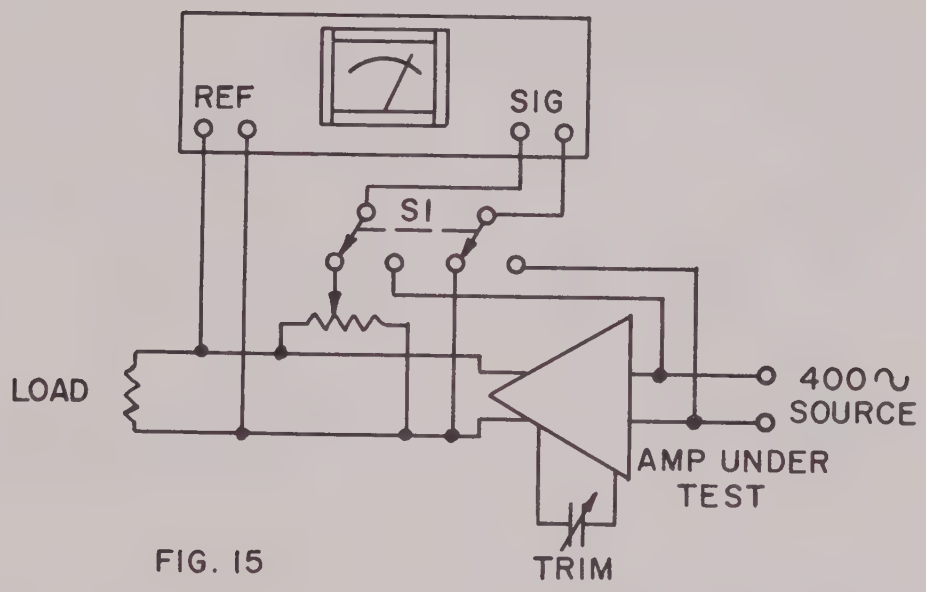

FIG. 15

Transformation Ratio

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure (16a) and (16b).

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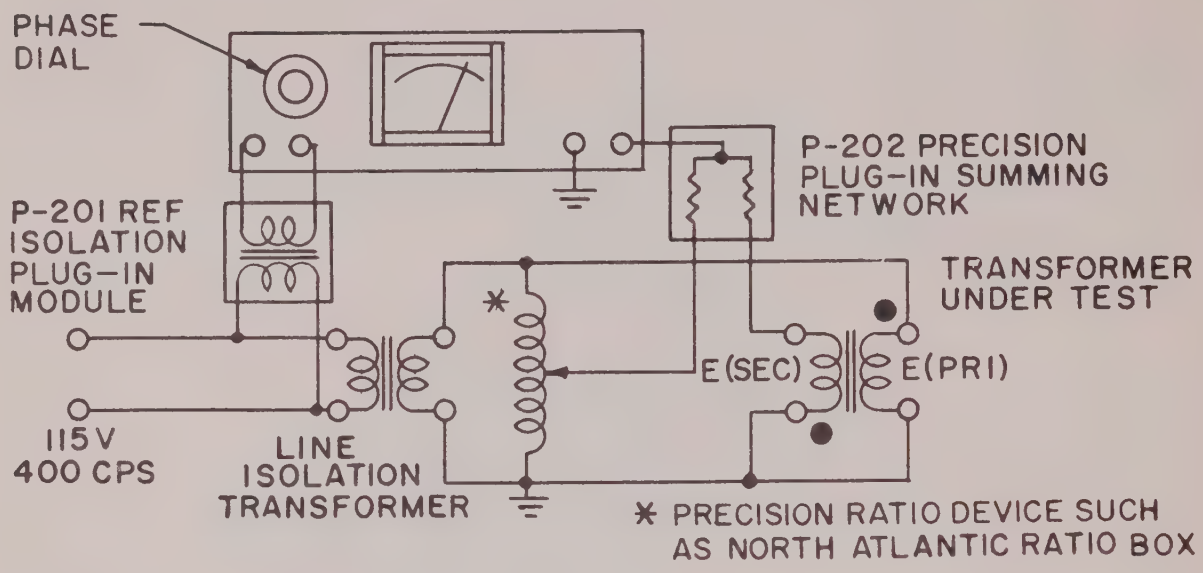

FIGURE 16(a)

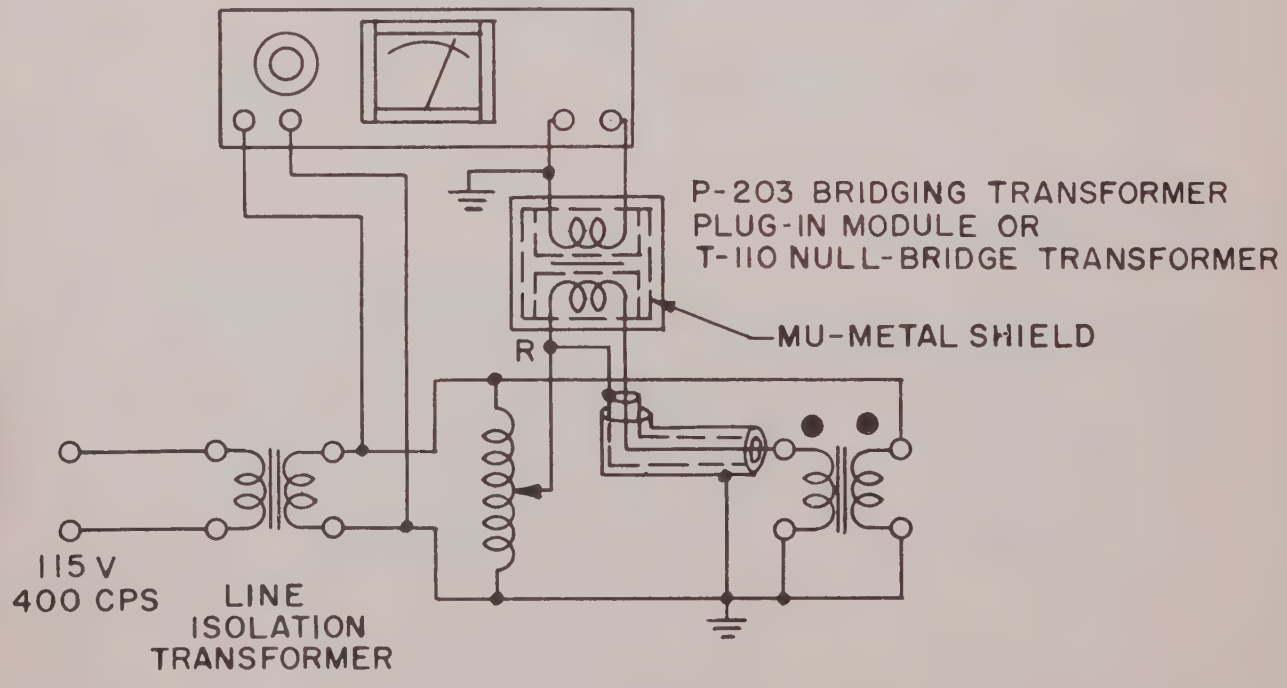

FIGURE 16(b)

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I. SUMMING NETWORK TECHNIQUES

In Figure (16a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test setup a line isolation transformer is utilized so as to avoid grounding one side of theline. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure (16a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure (16b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common-mode rejection and low input capacitance would suffice.

Measurement errors in Figure (16b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the Figure.

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Common-mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each setup must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both setups require that the Phase Dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc., This is conveniently done by stepping the ratio device and adjusting the Phase Dial to produce zero output when the Function Selector is in the 90^{o} position. Operation will then be correct when the Function Selector is returned to the 0^{o} position.

Small Angle Measurements

Small angle measurements to better than $.01^{o}$ can also be made using the setups of Figure (16). The process consists of making the in-phase null, described in the foreoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E sec}|} = \text{Tan}^{-1} \left(\frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}} \right)$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

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For Example:

Measured quadrature = 30.0 millivolts

Secondary voltage = 30 volts

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\simeq \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\equiv 0.001 \times 57.3 = .057 \text{ degrees}$$

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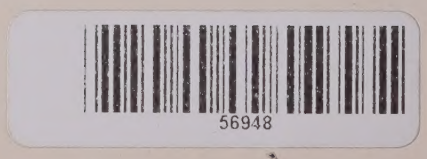
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